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OF. DE PARTES RECIBIDO
26 ENE 2011
MINISTERIO DEL MEDIO AMBIENTE

Santiago, 25 de enero de 2011
GG/MA/007/2011

Sra.
María Ignacia Benítez Pereira
Ministra de Medioambiente
Presente

Ref.: Observaciones al Anteproyecto de la Norma de Emisión para Incineración y Co-incineración, Decreto N°45 de 2007

De nuestra consideración:

En relación al proceso de revisión de la Norma de Emisión para la Incineración y Coincineración, establecido por resolución exenta Nº 15, de 19 de octubre de 2010, del Ministerio del Medio Ambiente adjunto enviamos nuestras observaciones y comentarios al anteproyecto de la norma.

Desde ya le manifestamos nuestro agradecimiento por la inclusión de nuestra empresa en el proceso de discusión de la norma que ha tenido lugar durante los últimos meses en sus dependencias.

Ante cualquier requerimiento relacionado con el motivo de esta carta, le agradeceré ponerse en contacto con nuestra Gerente de Asuntos Ambientales, la señora Marina Hermosilla, al teléfono 337 6458 o al correo electrónico marina.hermosilla@polpaico.cl

Sin otro particular, y agradeciendo su atención, le saluda atentamente

Cementos Polpaico S.A.

Louis Beauchemin
Gerente General Grupo Polpaico

MH/AJ/LC/EO/CB/SE

Adj. Documento de Observaciones

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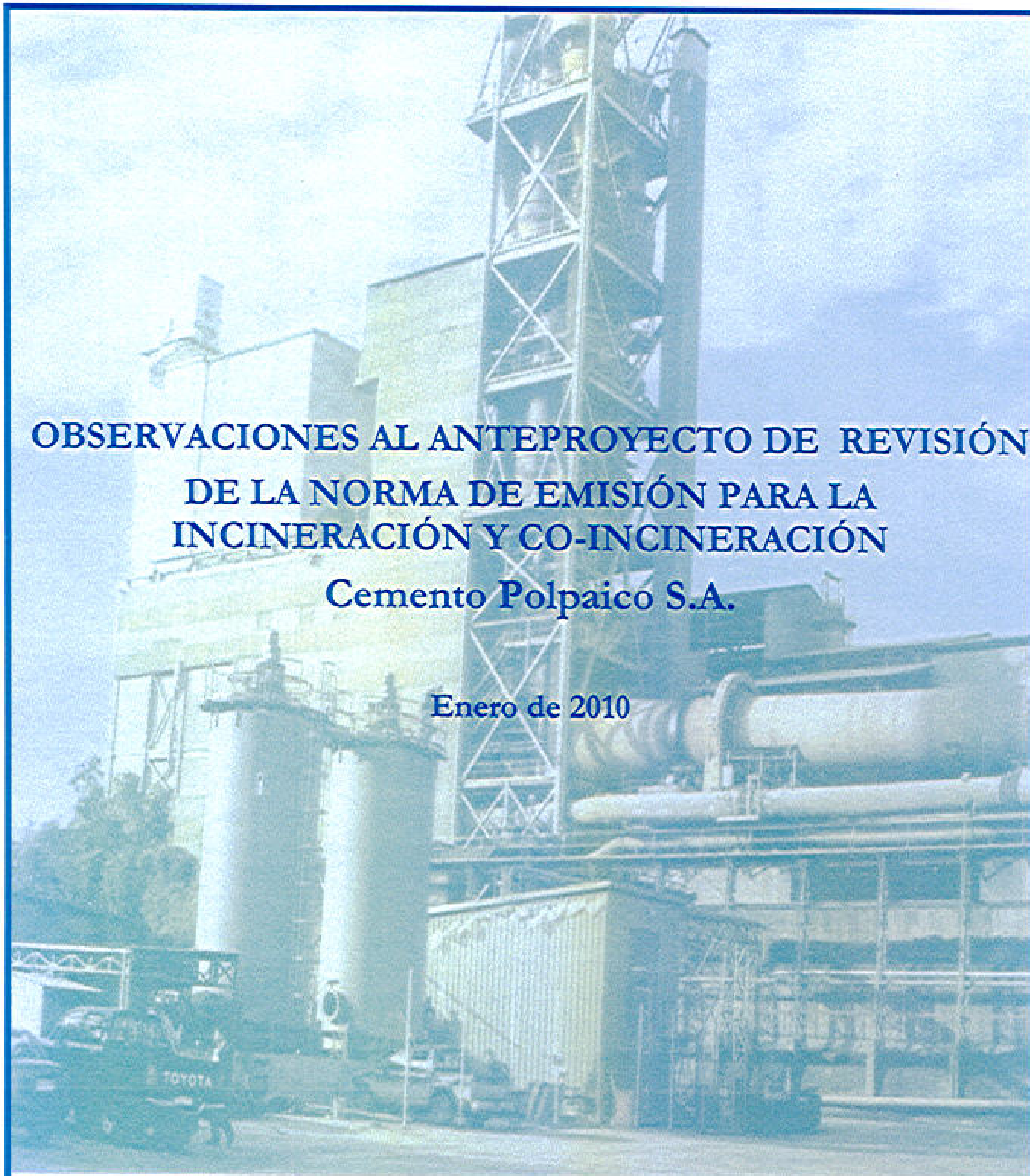

OBSERVACIONES AL ANTEPROYECTO DE REVISIÓN DE LA NORMA DE EMISIÓN PARA LA INCINERACIÓN Y CO-INCINERACIÓN

Cemento Polpaico S.A.

Enero de 2010

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OBSERVACIONES AL ANTEPROYECTO DE REVISIÓN DE LA NORMA DE EMISIÓN PARA LA INCINERACIÓN Y CO-INCINERACIÓN, DECRETO N°45 DE 2007, PUBLICADO MEDIANTE RESOLUCIÓN EXENTA Nº 15, DEL 19 DE OCTUBRE DE 2010, DEL MINISTERIO DEL MEDIO AMBIENTE.
Enero de 2010

1. Nombre de la Norma

A objeto de evitar confusiones inconvenientes, y siguiendo la tendencia internacional sobre el tema objeto de esta regulación, es nuestro interés que la nueva normativa se refiera al Tratamiento Térmico de Residuos, sin especificar *a priori* de qué tipo de tratamiento se trata. Como se explica en el punto siguiente, el tratamiento que se efectúa en los hornos cementeros no corresponde técnicamente a la incineración ni tampoco a la co-incineración, que se mencionan en el título del cuerpo legal actual.

2. Identificación de Tecnologías

Chile, a través del Ministerio de Salud como autoridad competente, ha propuesto para el Programa de Naciones Unidas para el Medio Ambiente (UNEP), en particular para la Convención de Basilea, las "Guías técnicas para el co-procesamiento de residuos peligrosos en hornos cementeros"[1], las que luego de su proceso de revisión se transformarán en un documento oficial de ese organismo. La comunicación formal de la Secretaría Ejecutiva de la Convención de Basilea donde se confía a Chile la elaboración de las mencionadas Guías Técnicas, y el borrador vigente de esta Guía se adjuntan en anexo a este documento.

Parece del todo razonable entonces, que futuras regulaciones del marco legal chileno que involucren a este tema, estén en sintonía con la terminología internacional, en este caso con la utilizada por Naciones Unidas a través de la Convención de Basilea, y consecuentemente utilizada por el mismo Estado de Chile, representado por el Ministerio de Salud, en la propuesta de las ya mencionadas Guías técnicas para co-procesamiento en hornos cementeros.

La Convención de Basilea reconoce al proceso que se produce en los hornos cementeros como **co-procesamiento**, y no como **co-incineración**, que en realidad se refiere a un proceso tecnológicamente diferente, por lo que creemos del todo razonable sean diferenciados en la nueva normativa nacional.

[1] "Technical Guidelines On Co-Processing Of Hazardous Waste In Cement Kilns" según su título oficial en Inglés.

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Solicitamos entonces incluir la definición de co-procesamiento utilizada en las guías técnicas para co-procesamiento en hornos cementeros del Convenio de Basilea que transcribimos a continuación:

> **"Uso de residuos adecuados en procesos de manufactura industrial, con el propósito de recuperar energía y/o recursos, con la consiguiente disminución en el uso de combustibles y/o materias primas tradicionales a través de substitución[2]".**

Así, la tecnología de co-procesamiento se refiere a la utilización de materiales de residuo en procesos industriales (cemento, cal, etc.) como reemplazo de combustibles y/o materias primas tradicionales. Es decir, corresponde simultáneamente a recuperación energética y reciclaje de materias primas minerales. Esta característica es fundamental para diferenciar co-procesamiento de co-incineración. Esta última solamente se refiere a recuperación energética, sin considerar materias primas.

Cabe agregar que esta doble recuperación que se logra con el co-procesamiento, es una de las bases para la revisión de la normativa europea que se lleva a cabo en la actualidad. La normativa que habla de incineración y co-incineración data del año 2000, cuando estas diferencias no eran claras para los organismos reguladores europeos.

Este reconocimiento que hace la Unión Europea sobre las diferencias entre los conceptos de co-incineración y co-procesamiento se puede constatar en los comentarios que realiza al borrador de Guías técnicas para co-procesamiento de la Convención de Basilea, en los que precisamente solicita que el documento aclare la diferencia entre ambas tecnologías (punto 6 de las observaciones generales del documento "EU Submission to Chile and the Basel Secretariat on the draft technical guidelines on co-processing of hazardous waste in cement kilns" copia de cuyo documento se anexa a esta presentación).

Como respuesta a este requerimiento de la Unión Europea, el último borrador de la guía técnica enviado por Chile a la UNEP aclara esa diferencia, incorporando la definición de co-incineración en el glosario y luego en el punto 1.1 (scope) - párrafo #3 de la guía (documento que se anexa).

Más allá de las diferencias en el alcance de ambas tecnologías, también se identifican diferencias técnicas, que se pueden resumir en el siguiente cuadro:

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[2] **Co-processing:** The use of suitable waste materials in manufacturing processes for the purpose of energy and/or resource recovery and resultant reduction in the use of conventional fuels and/or raw materials through substitution.

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CARACTERÍSTICAS	INCINERACIÓN	CO-INCINERACIÓN	CO-PROCESAMIENTO
Aprovechamiento térmico de residuos con contenido orgánico y reciclaje de energía	No	Sí	Sí
Aprovechamiento material de residuos con contenido inorgánico y reciclaje de materiales	No	No	Sí
Generación de cenizas necesarias de disponer	Sí	Sí	No
Temperaturas de operación	Hasta 1.200 °C	Hasta 1.200 °C	Hasta 2.000 °C
Combustión en ambiente altamente turbulento	No	No	Sí
Combustión en ambiente fuertemente alcalino.	No	No	Sí
Altos tiempos de residencia de gases en la zona de combustión.	Hasta 4-5 seg	Hasta 4-5 seg	> 6 seg.
Reducción global de emisiones (Ejemplo: CO_2)	No	Sí	Sí

El co-procesamiento como tecnología, está presente en las legislaciones modernas de países en desarrollo en torno al tratamiento térmico de residuos, tales como Brasil, México, Colombia, China, India, Sudáfrica, entre otros.

Destacan en este sentido algunas publicaciones y normativas internacionales sobre la materia, que se incluyen en anexo:

- Publicación WBCSD (World Business Council for Sustainable Development) – CSI (Cement Sustainability Innitiative) sobre combustibles y materias primas alternativas - 2005
- Guías sobre co-procesamiento publicadas por GTZ – Holcim – 2006
- Nueva norma de Emisión en Sud Africa – 2009 (se incluye en anexo)

Por las consideraciones anteriores, para utilizar un concepto único que concuerde con los compromisos internacionales que Chile ha asumido, en este caso con la Convención de Basilea, y atendiendo al hecho que el tratamiento térmico de residuos que se realiza en los hornos cementeros chilenos (actividad en crecimiento) incluye residuos destinados tanto al reemplazo de combustibles como de materias primas, es que parece procedente referirse y regular esta actividad bajo la denominación de co-procesamiento y no como co-incineración.

A continuación acompañamos algunas definiciones que sirven de respaldo a nuestra posición:

Co-procesamiento: Uso de residuos adecuados en procesos de manufactura industrial, con el propósito de recuperar energía y/o recursos, con la consiguiente disminución en el uso de combustibles y/o materias primas tradicionales a través de substitución. (UNEP – Basel Convention, Draft Technical guidelines on co-processing of hazardous waste in cement kilns – 2010)

"Instalación de Incineración": dedicado al tratamiento térmico de residuos con o sin recuperación del calor producido por la combustión, incluida la incineración por oxidación de residuos, así como la pirólisis, la gasificación u otros procesos de tratamiento térmico, por ejemplo el proceso de plasma, en la medida en que las sustancias resultantes del tratamiento se incineren a continuación. Esta definición comprende el emplazamiento y la instalación completa, incluidas todas las líneas de incineración y las instalaciones de recepción, almacenamiento y pretratamiento in situ de los residuos; los sistemas de alimentación de residuos, combustible y aire; la caldera; las instalaciones de tratamiento de los gases de combustión; las instalaciones de tratamiento o almacenamiento in situ de los residuos de la incineración y de las aguas residuales; la chimenea; así como los dispositivos y sistemas de control de las operaciones de incineración, de registro y de seguimiento de las condiciones de incineración. (DIRECTIVA 2000/76/CE – 2000, que se adjunta en anexo)

"Instalación de co-incineración": se define como toda instalación fija o móvil cuya finalidad principal sea la generación de energía o la fabricación de productos materiales y:

— que utilice residuos como combustible habitual o complementario, o
— en la que los residuos reciban tratamiento térmico para su eliminación.

Si la co-incineración tiene lugar de tal manera que el principal propósito de la instalación no sea la generación de energía o producción de productos materiales sino más bien el tratamiento térmico de residuos, la instalación se considerará como instalación de incineración en el sentido del punto anterior.

Esta definición comprende el emplazamiento y la instalación completa, incluidas todas las líneas de co-incineración y las instalaciones de recepción, almacenamiento y pre-tratamiento in situ de los residuos; los sistemas de alimentación de residuos, combustible y aire; la caldera; las instalaciones de tratamiento de los gases de combustión; las instalaciones de tratamiento o almacenamiento in situ de los residuos de la incineración y de las aguas residuales; la chimenea; así como los dispositivos y sistemas de control de las operaciones de incineración, de registro y de seguimiento de las condiciones de incineración. (DIRECTIVA 2000/76/CE - 2000)[3]

[3] Co-Incineration plant: Under Directive 2000/76/EC of the European Parliament and of the Council, any stationary or mobile plant whose main purpose is the generation of energy or production of material products and which uses wastes as a regular or additional fuel; or in which waste is thermally treated for the purpose of disposal. If co-incineration takes place in such a way that the main purpose of the plant is not the

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4. Tipo de monitoreo de las emisiones y acreditación del cumplimiento de la norma

El artículo 5° de la referida norma define que la frecuencia de las mediciones a las que deben someterse las instalaciones reguladas por el decreto en cuestión es anual; sin perjuicio de lo cual el mismo artículo establece también la necesidad de monitorear en continuo ciertos contaminantes dependiendo del tipo de instalación de que se trate.

Por su parte, el inciso segundo del artículo 6° define las condiciones en las que la norma de emisión se considerará sobrepasada para las mediciones en forma continua de acuerdo al tipo de instalación de que se trate.

Sin embargo, existen situaciones en las que las empresas tenemos obligación de monitorear en continuo más contaminantes que los que establece el Art. 5 de esta norma (debido a procesos de evaluación en el SEIA), en cuyos casos no queda claro cuándo se considerará sobrepasada la norma.

A modo de ejemplo, podemos decir que en Polpaico, los hornos de la planta Cerro Blanco cuentan con monitoreo continuo de emisiones de material particulado, O_2, CO, NOx, SO_2, COT, y HCl, los cuales fueron solicitados en la RCA 564/03 de la COREMA R.M. Según dicha RCA se debe acreditar cumplimiento de dichos parámetros "de acuerdo a la Norma de co-incineración mediante monitoreo continuo".

Ahora bien, para acreditar cumplimiento, entendemos que debemos calcular el promedio diario de emisión, sobre la base de los promedios horarios, considerando todos los valores que arrojan nuestros equipos de monitoreo continuo (cada 20 segundos).

Sin embargo, esta es sólo una interpretación nuestra de la mencionada norma, de la cual se le pidió a la Autoridad Sanitaria un pronunciamiento mediante carta enviada en enero de 2008 y de la cual no recibimos nunca una respuesta.

Es entonces del todo deseable que quede establecido claramente en la norma revisada, la forma de acreditar cumplimiento para cada uno de los parámetros, tanto si se cuenta con monitoreo continuo como discreto. Más aún cuando la tendencia es a certificar los equipos de monitoreo continuo, de manera que no sea necesario contar con monitoreos discretos de terceros.

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generation of energy or production of material products but rather the thermal treatment of waste, the plant shall be regarded as an incineration plant.

5. Definición de COT y COV, así como también la relación entre ellos.

Se hace necesario precisar qué se entiende por COT y COV para efectos de la norma, dado que existen varias definiciones para estos términos. A modo de ejemplo podemos citar a la Agencia de Protección Ambiental de Estados Unidos (USEPA), que define COV como "cualquier compuesto orgánico que participa en una foto reacción". Sin embargo, esta definición es poco precisa ya que algunos compuestos orgánicos que no son "volátiles", en el sentido que se evaporan bajo condiciones normales, pueden ser considerados como volátiles según ésta.

Por su parte la legislación Suiza, en su reciente "Ordenanza sobre aranceles a pagar por emisiones de COV", define a éstos como: "Aquellos compuestos orgánicos de al menos 0,1 milibares a 20ºC o con un punto de ebullición de máximo 240 ºC a 1013,25 milibares (presión de vapor)".

Por otro lado, Perry y Gee entienden por COV a "Cualquier sustancia orgánica liberada como vapor a la atmósfera, con potencialidad para causar efectos a bajas concentraciones".

Así entonces, existiendo varias posibilidades de interpretar el significado de COV, y no quedando claramente definida su relación con COT, estos últimos también se prestan a interpretaciones.

Se solicita que quede establecido en las definiciones de la norma, la definición de COT y COV, sus respectivas unidades y la relación entre ellos.

6. Aclaración de las unidades de medición para COV ó COT

Se hace necesario incluir en el Titulo I la unidad de concentración de los COV o COT en mg C/N m^3 y los respectivos cálculos en función del gas de calibración del equipo.

Cuando se transforma una concentración de metano o compuestos orgánicos volátiles de ppm a mg/m^3 N se debe considerar el gas de calibración que se esté utilizando, ya que de esta forma se podrá llevar a la misma unidad de concentración para ser sumados como compuestos orgánicos totales.

Lo anterior se detalla a continuación utilizando un ejemplo real de medición en la planta Cerro Blanco de Cemento Polpaico.

1. Se transforma la concentración del compuesto en unidades de ppm a mg/m^3 del gas de calibración utilizado.

Considerando comportamiento de gas ideal y resultados de medición, se tiene:

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- Comportamiento de gas ideal: V/n= 24,4 L/mol a 1atm y 25 ºC

- Medición con método CH-25 A en Ensayo de Verificación 2009 Horno 1 de Cemento Polpaico:

COV = 6,1 ppm calibrado con gas propano
CH_4 = 2,4 ppm calibrado con gas metano

$$COV \rightarrow \frac{mgC_3H_8}{m^3} = 6{,}1\,ppm * \frac{44}{24{,}4} = 11$$

$$CH_4 \rightarrow \frac{mgCH_4}{m^3} = 2{,}4\,ppm * \frac{16}{24{,}4} = 1{,}57$$

2. Se transforma la concentración del compuesto en unidades de mg/m³ del gas de calibración utilizado a mg/m³ en base a carbono.

$$COV \rightarrow \frac{mgC}{m^3} 6{,}1\,ppm * \frac{36}{24{,}4} = 9$$

$$CH_4 \rightarrow \frac{mgC}{m^3} = 2{,}4\,ppm * \frac{12}{24{,}4} = 1{,}18$$

3. Se suma la concentración en base a carbono del COV y metano para obtener los COT

$$COT = COV + CH_4 = 9 + 1{,}18 = 10{,}18 \frac{mgC}{m^3}$$ Este resultado es correcto.

Si se hubiese sumado sin considerar la transformación en base a carbono según el gas de calibración utilizado en la medición, tendríamos el siguiente resultado.

$$COT = COV + CH_4 = 11 + 1{,}57 = 12{,}57 \frac{mgC}{m^3}$$ Este resultado es incorrecto.

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Se recomienda incluir estos cálculos, ya sea en el cuerpo normativo, en el manual de aplicación de la norma o bien en el método CH_25 A, con el fin de estandarizar todas las mediciones de compuestos orgánicos expresándolas en la misma unidad de mg de Carbono por unidad de volumen.

5. Criterio para cumplimiento límite COT en co-procesamiento en hornos cementeros y de cal

La norma actualmente considera excepciones en este caso, indicando que:

> *"La autoridad competente autorizará exenciones a este límite en los casos en que el COT no provenga de las sustancias o materiales utilizadas como combustible. Para ello los titulares deberán presentar antecedentes fundados."*

Si bien esta nota se considera del todo pertinente, a efectos de disminuir la discrecionalidad y evitar procesos largos e inconducentes, se solicita incluir en la nueva normativa los criterios objetivos y cuantificables que serán solicitados para demostrar la procedencia de las emisiones.

Al efecto, se recomienda la siguiente redacción:

"La autoridad competente autorizará exenciones a este límite en los casos en que el COT no provenga de las sustancias o materiales co-procesados. Para ello los titulares deberán presentar antecedentes fundados en base a la determinación de la línea de base correspondiente en función del combustible y materia prima tradicionales utilizados. El límite de emisión a considerar en este caso corresponderá a esa línea de base más el valor indicado en la Tabla N°2"

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Anexo 1

Draft Technical Guidelines On Co-Processing Of Hazardous Waste In Cement Kilns

Basel Secretariat
November 2010 Version

Draft Technical Guidelines on Co-processing of Hazardous Waste in Cement Kilns

(Version 15 November 2010)

Glossary

Accuracy: A measure of the overall agreement of a measurement to a known value; includes a combination of random error (precision) and systematic error (bias) components of both sampling and analytical operations.

Aggregates: Particulate materials such as sand, gravel, crushed stone and crushed slag, used in construction.

Alkali bypass: A duct between the feed end of the kiln and the preheater tower through which a portion of the kiln exit gas stream is withdrawn and quickly cooled by air or water to avoid excessive build-up of alkali, chloride and/or sulphur on the raw feed. This may also be referred to as the 'kiln exhaust gas bypass'.

Alternative fuels and raw materials (AFR): Inputs to clinker production derived from waste streams that contribute energy and/or raw material.

Alternative fuels: Wastes with recoverable energy value used as fuels in a cement kiln, replacing a portion of conventional fossil fuels, like coal. These are sometimes termed secondary, substitute or waste-derived fuels, among others.

Alternative raw materials: Wastes containing useful minerals such as calcium, silica, alumina, and iron used as raw materials in the kiln, replacing raw materials such as clay, shale, and limestone. These are sometimes termed secondary or substitute raw materials.

Audit: A systematic and independent examination to determine whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives.

Best available techniques (BAT): The most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole.

Bypass dust: Discarded dust from the bypass system dedusting unit of suspension preheater, precalciner and grate preheater kilns, consisting of fully calcined kiln feed material.

Calcination: The heat-induced removal, or loss, of chemically-bound volatiles, usually other than water. In cement manufacture it involves the thermal decomposition of calcite (calcium carbonate) and other carbonate minerals to a metallic oxide (mainly CaO) plus carbon dioxide.

Cement kiln dust (CKD): The fine-grained, solid, highly alkaline material removed from cement kiln exhaust gas by air pollution control devices. Much of the material comprising CKD is actually unreacted raw material, including raw mix at various stages of burning and particles of clinker. The term CKD is sometimes used to denote all dust from cement kilns, i.e. also from bypass systems.

Cement: Finely ground inorganic material which, when mixed with water, forms a paste which sets and hardens by means of hydration reactions and processes and which, after hardening, retains its strength and stability under water.

Clinkering: The thermochemical formation of the actual clinker minerals, especially to those reactions occurring above about 1300°C; also the zone in the kiln where this occurs. Also known as sintering or burning.

Co-Incineration plant: Under Directive 2000/76/EC of the European Parliament and of the Council, any stationary or mobile plant whose main purpose is the generation of energy or production of material products and which uses wastes as a regular or additional fuel; or in which waste is thermally treated for the purpose of disposal. If co-incineration takes place in such a way that the main purpose of the plant is not the generation of energy or production of material products but rather the thermal treatment of waste, the plant shall be regarded as an incineration plant..

Comparability: A qualitative term that expresses the measure of confidence that one data set can be compared to another and can be combined for the decision(s) to be made.

Completeness: A measure of the amount of valid data needed to be obtained from a measurement system.

Concrete: Building material made by mixing a cementing material (such as portland cement) along with aggregate (such as sand and gravel) with sufficient water and additives to cause the cement to set and bind the entire mass.

Conventional (fossil) fuels: Non-renewable carbon-based fuels traditionally used in cement manufacturing, including coal and oil.

Co-processing: The use of suitable waste materials in manufacturing processes for the purpose of energy and/or resource recovery and resultant reduction in the use of conventional fuels and/or raw materials through substitution.

Destruction and removal efficiency (DRE): Efficiency in destruction and removal of a given organic compound. Mathematically, DRE is calculated as follows:

$$\mathrm{DRE} = [(W_{\mathrm{in}} - W_{\mathrm{out\ stack}})/W_{\mathrm{in}}] \times 100$$

where W_{in} is the mass feed rate of one principal organic hazardous constituent (POHC) in the waste stream fed to the kiln, and $W_{\mathrm{out\ stack}}$ is the mass emission rate of the same POHC in the exhaust emissions prior to release to the atmosphere.

Destruction efficiency (DE): A measure of the percentage of a given organic compound that is destroyed by the combustion process. Mathematically, DE is calculated as follows:

$$\mathrm{DE} = [(W_{\mathrm{in}} - W_{\mathrm{out\ combustion\ chamber}})/W_{\mathrm{in}}] \times 100$$

where W_{in} is the mass feed rate of one principal organic hazardous constituent (POHC) in the waste stream fed to the kiln, and $W_{\mathrm{out\ combustion\ chamber}}$ is the mass emission rate of the same POHC leaving the kiln (upstream of all air pollution control equipment). The DE represents the fraction of the organics entering a kiln which is actually destroyed; the DRE represents the fraction of the organics entering a kiln which is emitted from the stack to the atmosphere.

Disposal: Any operation specified in Annex IV to the Basel Convention ("Disposal operations")

Dry process: Process technology for cement production. In the dry process, the raw materials enter the cement kiln in a dry condition after being ground to a fine powder (raw meal). The dry process is less energy consuming than the wet process, where water is added to the raw materials during grinding to form a slurry.

Emissions testing: Manual collection of stack gas sample(s), followed by chemical analysis to determine pollutant concentrations.

Environmental impact assessment (EIA): An examination, analysis and assessment of planned activities with a view to ensuring environmentally sound and sustainable development. Criteria for determining the requirement for an EIA should be clearly defined in legal/policy sources.

Environmentally sound management (ESM): Taking all practicable steps to ensure that hazardous wastes or other wastes are managed in a manner which will protect human health and the environment against the adverse effects which may result from such wastes.

Hazardous wastes: Wastes that belong to any category contained in Annex I to the Basel Convention ("Categories of wastes to be controlled"), unless they do not possess any of the characteristics contained in Annex III to the Convention ("List of hazardous characteristics"): explosive; flammable liquids; flammable solids; substances or wastes liable to spontaneous combustion; substances or wastes which, in contact with water, emit flammable gases; oxidizing; organic peroxides; poisonous (acute); infectious substances; corrosives; liberation of toxic gases in contact with air or water; toxic (delayed or chronic); ecotoxic; capable, by any means, after disposal, of yielding another material, e.g. leachate, which possesses any of the other characteristics.

Heating (calorific) value: The heat per unit mass produced by complete combustion of a given substance. Calorific values are used to express the energy values of fuels; usually these are expressed in megajoules per kilogram (MJ/kg).

Higher heating (calorific) value (HHV): Maximum amount of energy that can be obtained from the combustion of a fuel, including the energy released when the steam produced during combustion is condensed. It is sometimes called the gross heat value.

Hydraulic cement: A cement that sets and hardens by chemical interaction with water and that is capable of doing so under water.

Kiln line: The part of the cement plant that manufactures clinker; comprises the kiln itself plus any preheaters and precalciners, plus the clinker cooler apparatus.

Kiln: The heating apparatus in a cement plant in which clinker is manufactured. Unless otherwise specified, may be assumed to refer to a rotary kiln.

Life Cycle Assessment (LCA): objective process to evaluate the environmental burdens associated with a product, process or activity by identifying and quantifying energy and materials used and wastes released to the environment, to assess the impact of those energy and materials uses and releases to the environment, and to evaluate and implement opportunities to affect environmental improvements. The assessment includes the entire life cycle of the product, process or activity, encompassing extracting and processing raw materials; manufacturing, transportation and distribution; use, reuse and maintenance; recycling and final disposal.

Lower heating (calorific) value (LHV): The higher heating value less the latent heat of vaporisation of the water vapour formed by the combustion of the hydrogen in the fuel. It is sometimes called the net heat value.

Manifest: Shipping document that travels with hazardous waste from the point of generation, through transportation, to the final disposal facility, creating a 'cradle-to-grave' tracking of the hazardous waste.

Operator: Any natural or legal person who operates or controls the installation or facility.

Portland cement clinker: A hydraulic material which consists of at least two-thirds by mass of calcium silicates ($(CaO)_3 \cdot SiO_2$ and $(CaO)_2 \cdot SiO_2$), the remainder containing aluminium oxide (Al_2O_3), iron oxide (Fe_2O_3) and other oxides.

Portland cement: A hydraulic cement produced by pulverising Portland-cement clinker, and usually containing calcium sulphate.

Precalciner: A kiln line apparatus, usually combined with a preheater, in which partial to almost complete calcination of carbonate minerals is achieved ahead of the kiln itself, and which makes use of a separate heat source. A precalciner reduces fuel consumption in the kiln, and allows the kiln to be shorter, as the kiln no longer has to perform the full calcination function.

Precision: The measure of agreement among repeated measurements of the same property under identical, or substantially similar conditions; calculated as either the range or as the standard deviation. May also be expressed as a percentage of the mean of the measurements, such as relative range or relative standard deviation (coefficient of variation).

Preheater: An apparatus used to heat the raw mix before it reaches the dry kiln itself. In modern dry kilns, the preheater is commonly combined with a precalciner. Preheaters make use of hot exit gases from the kiln as their heat source.

Pre-processing: Alternative fuels and/or raw materials not having uniform characteristics must be prepared from different waste streams before being used as such in a cement plant. The preparation process, or pre-processing, is needed to produce a waste stream that complies with the technical and administrative specifications of cement production and to guarantee that environmental standards are met.

Pyroprocess system: Includes the kiln, cooler, and fuels combustion equipment.

Quality assurance (QA): A system of management activities involving planning, implementation, assessment, and reporting to make sure that the end product (for example, environmental data) is of the type and quality needed to meet the needs of the user.

Quality control (QC): Overall system of operational techniques and activities that are used to fulfil requirements for quality.

Raw mix/meal/feed: The crushed, ground, proportioned, and thoroughly mixed raw material-feed to the kiln line.

Recovery: Any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy.

Representative sample: A sample of a universe or whole (for example, waste pile) which can be expected to exhibit the average properties of the universe or whole.

Representativeness: A qualitative term that expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition.

Rotary kiln: A kiln consisting of a gently inclined, rotating steel tube lined with refractory brick. The kiln is fed with raw materials at its upper end and heated by flame from, mainly, the lower end, which is also the exit end for the product (clinker).

Trial burn: Emissions testing performed for demonstrating compliance with the destruction and removal efficiency (DRE) and destruction efficiency (DE) performance standards and regulatory emission limits; is used as the basis for establishing allowable operating limits.

Vertical shaft kiln (VSK): A vertical, cylindrical or chimney-type kiln, heated from the bottom, which is fed either with a batch or continuous charge consisting of an intimate mix of fuel and raw materials. Generally considered obsolete for cement manufacture. VSK technology is based on a black meal process, which prevents the use of alternative fuels.

Waste (management) hierarchy: List of waste management strategies arranged in order of preference, with waste prevention being the most desirable option and disposal the least preferred approach. Departing from such hierarchy may be necessary for specific waste streams when justified for reasons of, inter alia, technical feasibility, economic viability and environmental protection.

Wastes: Substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law.

Acronyms

ACGIH	American Conference of Governmental Industrial Hygienists (http://www.acgih.org/)
ASTM	American Society for Testing and Materials (http://www.astm.org/)
BAT	Best Available Technique
BAT-AEL	BAT Associated Emission Level
BEP	Best Environmental Practice
BREF	Reference Document on Best Available Techniques (as published by the EIPPCB, http://eippcb.jrc.es/)
CCME	Canadian Council of Ministers of the Environment (http://www.ccme.ca/)
CEM	Continuous Emission Monitoring Systems
CEN	European Committee for Standardization (http://www.cen.eu/)
CKD	Cement Kiln Dust
CLM BREF	Reference Document on Best Available Techniques for the Cement, Lime and Magnesium Oxide Manufacturing (as published by the EIPPCB, http://eippcb.jrc.es/)
DE	Destruction Efficiency
DRE	Destruction and Removal Efficiency
EA	Environment Agency of England and Wales (http://www.environment-agency.gov.uk/)
EIPPCB	European Integrated Pollution Prevention Control Bureau (http://eippcb.jrc.es/)
EPA	United States Environmental Protection Agency (http://www.epa.gov/)
EU	European Union
ESM	Environmentally Sound Management
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (http://www.gtz.de/)
HAP	Hazardous Air Pollutant
ICP	Inductively Coupled Plasma
IOELV	Indicative Occupational Exposure Limit Value
IPCC	Intergovernmental Panel on Climate Change
IPPC	Integrated Pollution Prevention and Control
I-TEQ	International Toxic Equivalent
LCA	Life Cycle Assessment
MSDS	Material Safety Data Sheets
NIOSH	National Institute for Occupational Health and Safety of the United States (http://www.cdc.gov/niosh/)
OECD	Organisation for Economic Co-operation and Development (http://www.oecd.org/)
OSHA	Occupational Safety and Health Administration of the United States (http://www.osha.gov/)
PAH	Polycyclic Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl

PCDD	Polychlorinated Dibenzo-p-Dioxin
PCDF	Polychlorinated Dibenzo-Furan
PEL	Permissible Exposure Limit
PIC	Product of incomplete combustion
POHC	Principal Organic Hazardous Constituent
POP	Persistent Organic Pollutant
PPE	Personal Protective Equipment
QA	Quality Assurance
QC	Quality Control
RII	Resource-Intensive Industries
SBC	Secretariat of the Basel Convention (http://www.basel.int/)
TEQ	Toxic Equivalent
THC	Total Hydrocarbon
TLV	Threshold Limit Value
TOC	Total Organic Compounds
UNEP	United Nations Environment Programme (http://www.unep.org/)
VOC	Volatile Organic Compound
WAP	Waste Analysis Plan
WBCSD	World Business Council for Sustainable Development (http://www.wbcsd.org/)
XRF	X-Ray Fluorescence

Contents

1.Introduction

1.1. Scope

1. The present general technical guidelines provide general guidance on co-processing of hazardous waste as alternative fuels and raw materials in cement kilns, pursuant to decisions VIII/17 and IX/17 of the Conference of the Parties to the Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and Their Disposal and decision VII/9 of the Open-ended Working Group of the Basel Convention.

2. Co-processing of waste materials in properly controlled cement kilns provides energy and materials recovery while cement is being produced and offers an environmentally sound recovery option for many of society's wastes. As countries strive for greater self-sufficiency in hazardous waste management where this is technically and economically feasible, particularly in developing nations, which may have little or no waste management infrastructure, properly designed and operated cement kilns can provide a practical, cost-effective and environmentally preferred option (in line with the Waste Management Hierarchy) to landfill and incineration, through the co-processing of waste materials. Co-processing of waste in resource-intensive processes in general, can be an important element in a more sustainable system of managing raw materials and energy.

3. Although the substitution of fossil fuels with alternatives is viewed by some stakeholders and jurisdictions in the same light as incineration, it is nevertheless a well-developed practice in a number of countries, and some national governments actively promote this approach, provided that stringent requirements with regard to input, process and emission control are met. The term "co-processing" should not be confused with "co-incineration"; the latter refers to the production of material products while using wastes as fuel or the plant in which waste is thermally treated for the purpose of disposal. The former however refers to the utilisation of alternative fuel and/or raw materials for the purpose of energy and/or resource recovery.

4. These guidelines are considered to be current best practice at the time of writing and should not be regarded as providing a conclusive indication of appropriate action. Neither should they be regarded as prescriptive or a clear recommendation to use an option in all cases. They provide a general orientation concerning the conditions in which co-processing can currently be applied and will require regular update in order to incorporate advances as they arise.

5. While these technical guidelines refer to hazardous waste as defined by the Basel Convention, it is noted that because the selection of wastes suitable for co-processing in cement kilns is influenced by many factors other than the hazardous characteristic(s) exhibited by the waste itself, some recommendations may also apply to the co-processing of non hazardous waste in cement kilns. It should also be noted that these guidelines do not cover quarrying or the re-use of concrete, nor the use of waste materials as a substitute for clinker.

1.2. General Provisions of the Basel Convention

6. The Basel Convention, which entered into force on 5 May 1992, stipulates that any transboundary movement of wastes (export, import, or transit) is permitted only when the movement itself and the disposal of the concerned hazardous or other wastes are environmentally sound.

7. In its Article 2 ("Definitions"), paragraph 1, the Basel Convention defines wastes as "substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law". In paragraph 4 of that Article, it defines disposal as "any operation specified in Annex IV" to the Convention. In paragraph 8, it defines the environmentally sound management (ESM) of hazardous wastes or other wastes as "taking all practicable steps to ensure that hazardous wastes or other wastes are managed in a manner which will protect human health and the environment against the adverse effects which may result from such wastes".

8. Article 4 ("General obligations"), paragraph 1, establishes the procedure by which Parties exercising their right to prohibit the import of hazardous wastes or other wastes for disposal shall inform the other Parties of their decision. Paragraph 1 (a) states: "Parties exercising their right to prohibit the import of hazardous or other wastes for disposal shall inform the other Parties of their decision pursuant to Article 13." Paragraph 1 (b) states: "Parties shall prohibit or shall not permit the export of hazardous or other wastes to the Parties which have prohibited the import of such waste when notified pursuant to subparagraph (a)."

9. Article 4, paragraphs 2 (a)-(d), contains key provisions of the Basel Convention pertaining to ESM, waste minimization, and waste disposal practices that mitigate adverse effects on human health and the environment:

"Each Party shall take appropriate measures to:

(a) Ensure that the generation of hazardous wastes and other wastes within it is reduced to a minimum, taking into account social, technological and economic aspects;

(b) Ensure the availability of adequate disposal facilities, for the environmentally sound management of hazardous wastes and other wastes, that shall be located, to the extent possible, within it, whatever the place of their disposal;

(c) Ensure that persons involved in the management of hazardous wastes or other wastes within it take such steps as are necessary to prevent pollution due to hazardous wastes and other wastes arising from such management and, if such pollution occurs, to minimize the consequences thereof for human health and the environment;

(d) Ensure that the transboundary movement of hazardous wastes and other wastes is reduced to the minimum consistent with the environmentally sound and efficient management of such wastes, and is conducted in a manner which will protect human health and the environment against the adverse effects which may result from such movement".

1.3. Overview of Cement Manufacturing

10. Cement is a finely ground, non-metallic, inorganic powder, which, when mixed with water forms a paste that sets and hardens. It is the key constituent of concrete, which is the second most consumed material worldwide after water. Cement production involves the heating, calcining and sintering of a carefully proportioned mixture of calcareous and argillaceous materials, usually limestone and clay, to produce cement clinker, which is then cooled and ground with additives such as gypsum (a setting retardant) to make cement. The most widely used production process for Portland cement clinker is the dry process, which is gradually replacing the wet process. The manufacturing process is described in more detail in Annex 1.

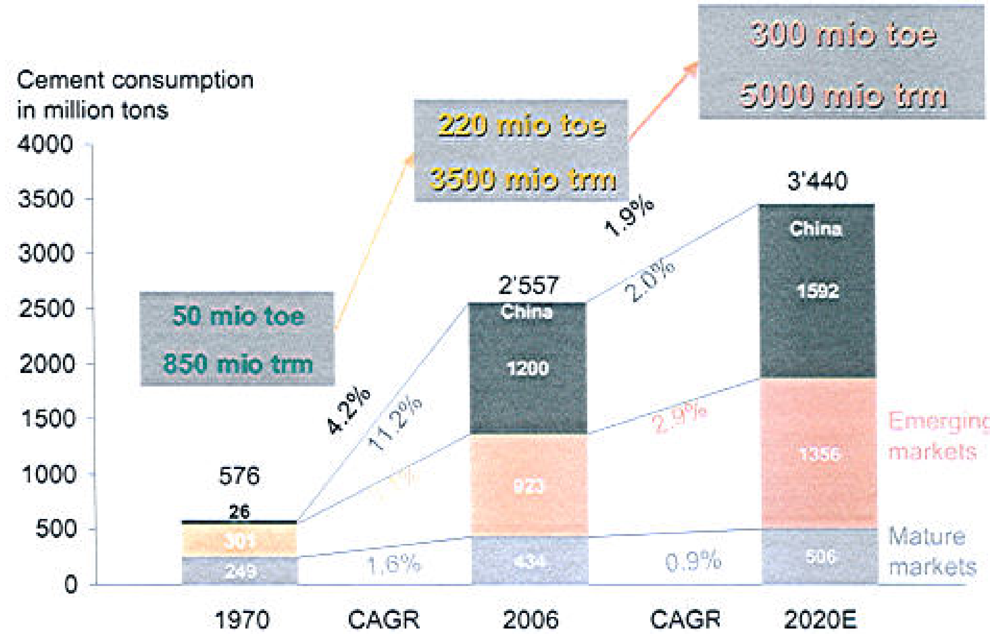
11. Cement manufacture is a resource intensive process. Normally about 1,5 to 1,7 tonnes of raw materials are quarried per tonne of clinker produced. In addition, the manufacturing process of clinker requires substantial energy in order to bring the kilns to temperatures of over 2000 °C. According to CEMBUREAU, the representative organization of the cement industry in Europe, each tonne of cement produced typically requires 60 to 130 kilograms of fuel oil or its equivalent, depending on the cement type and kiln technology employed, and about 105 KWh of electricity (Loréa, 2007). On average, energy costs (in the form of fuel and electricity) represent 40 percent of cement manufacturing costs (EIPPCB, 2010).

12. In 2008, global cement production was estimated to be 2.9 billion tonnes, with China responsible for about half of the world's production (Da Hai et al., 2010; U.S. Geological Survey, 2009). Consumption of cement is driven primarily by activity in the construction industry, and so is closely linked to the economic cycle. World cement consumption could reach 3,4 billion tonnes by 2020 (Figure 1), with the corresponding increases in energy, raw materials needs and pollutant mass emissions..

13. The cement industry has undergone significant consolidation over the past decade through mergers and acquisitions, becoming increasingly characterised by the presence of large, multinational firms. This notwithstanding, it remains a sector with a fairly low global market concentration with the five largest companies accounting for less than 20 percent of global output[1].

[1] According to data obtained from company annual reports: Lafarge (France), Holcim (Switzerland), Cemex (Mexico), Anhui Conch (China), HeidelbergCement (Germany).

Figure 1. Estimated world demand of cement



toe = tons of oil equivalent (42 GJ) ; trm = tons of raw material ; CAGR = Compound annual growth rate

Source: Degré (2009)

14. The clinker burning process is the most important part of the production process in terms of the key environmental issues associated with cement manufacture: energy use and emissions to air. Depending on the specific production processes, cement plants cause emissions to air and waste emissions to land (including cement kiln dust, CKD, where recycling back into the production process may be restricted). In specific rare cases, emissions to water may occur. Additionally, the environment can be affected by noise and odours. The key pollutants released to air are particulates, nitrogen oxides (NO_X) and sulphur dioxide (SO_2) (EIPPCB, 2010). Carbon oxides (CO, CO_2), polychlorinated dibenzo-p-dioxins and dibenzofurans (PCCDs/PCDFs), volatile organic compounds (VOC), metals and their compounds, hydrogen chloride (HCl) and hydrogen fluoride (HF) are emitted as well. Worldwide, cement making is thought to account for 6 percent of the total carbon dioxide (CO_2) emissions from stationary sources (IPCC, 2005). The type and quantity of air emissions depend on different parameters, for example, inputs (the raw materials and fuels used) and the type of process applied. Cement manufacturing operations are also associated with impacts of resource extraction (fossil fuel, limestone, and other minerals) upon environmental quality, biodiversity, and landscape aesthetics; and depletion of non-renewable or slowly renewable resources (fossil fuels or groundwater) (Battelle, 2002).

1.4. Co-processing of Hazardous Waste in Cement Kilns

15. Co-processing in resource-intensive industries (RII) involves the use of waste materials in manufacturing processes for the purpose of energy and/or resource recovery and resultant reduction in the use of conventional fuels and/or raw materials through substitution. In particular, the co-processing of hazardous waste materials in cement kilns, the subject of these guidelines, allows the recovery of the energy and/or mineral value from waste materials, while cement is being produced.

16. Co-processing is a sustainable development concept based on the principles of industrial ecology (Mutz et al., 2007; Karstensen, 2009a), a discipline that focuses on the potential role of industry in reducing environmental burdens throughout the product life-cycle. One of the most important goals of industrial ecology is to make one industry's waste another's raw material (OECD, 2000). Within the cement industry, the use of wastes as fuel and/or raw materials is an example of this type of exchange.

17. In co-processing, wastes serve a useful purpose in replacing part of the materials which would have had to be used for fuel and/or raw materials, thereby conserving natural resources; as such, under the Basel

Convention co-processing constitutes an operation "which may lead to resource recovery [2], recycling, reclamation, direct reuse or alternative uses" under R1 ("use as a fuel or other means to generate energy") and/or R5 ("recycling/reclamation of other inorganic materials") of Annex IVB to the Convention.

18. The Basel Convention places obligations on countries that are Parties to ensure the ESM of hazardous and other wastes. In this regard, the guiding principle broadly accepted for securing a more sustainable waste management system is the waste hierarchy of management practices (with due consideration given to the protection of the environment and human health) which places waste prevention (avoidance) and operations which may lead to resource recovery, recycling reclamation, direct re-use or alternative uses, in a preeminent position relative to operations which do not lead to such possibility. Thus, where waste avoidance is not possible, reuse, recycling and recovery becomes, in many cases, a preferable alternative to non recovery operations. To this end, co-processing in cement kilns provides an environmentally sound resource recovery option for the management of hazardous and other wastes, preferable to landfilling and incineration.

19. Fossil fuels and raw materials have been successfully substituted by different types of wastes in cement kilns in Europe, Japan, United States, Canada and Australia since the beginning of the 1970s (GTZ/Holcim, 2006). The experience of various jurisdictions with the use of hazardous and non-hazardous wastes as fuels and/or raw materials in cement kilns is reviewed by CCME (1996), EA (1999a), Twigger et al. (2001) and Karstensen (2007a), among others.

20. Although the practice varies among individual plants, cement manufacture can consume significant quantities of wastes as fuel and non-fuel raw materials. This consumption reflects the process characteristics in clinker kilns, that ensures the complete breakdown of the raw materials into their component oxides and the recombination of the oxides into the clinker minerals. The essential process characteristics for the use of hazardous and other wastes, fed to the kiln via appropriate feed points, can be summarised as follows (EIPPCB, 2010):

- Maximum temperatures of approximately 2000°C (main firing system, flame temperature) in rotary kilns;
- Gas retention times of about 8 seconds at temperatures above 1200°C in rotary kilns;
- Material temperatures of about 1450°C in the sintering zone of rotary kilns;
- Oxidising gas atmosphere in rotary kilns;
- Gas retention time in the secondary firing system of more than 2 seconds at temperatures above 850°C; in the precalciner, the retention times are correspondingly longer and temperatures are higher;
- Solids temperatures of 850°C in the secondary firing system and/or the calciner;
- Uniform burnout conditions for load fluctuations due to the high temperatures at sufficiently long retention times;
- Destruction of organic pollutants due to the high temperatures at sufficiently long retention times;
- Sorption of gaseous components like HF, HCl, and SO_2 on alkaline reactants;
- High retention capacity for particle-bound heavy metals;
- Short retention times of exhaust gases in the temperature range known to lead to formation of PCDDs/PCDFs;
- Complete utilisation of fuel ashes as clinker components and hence, simultaneous material recycling and energy recovery;
- Product specific wastes are not generated due to a complete material utilisation into the clinker matrix (although some cement plants dispose of CKD or bypass dust);
- Chemical-mineralogical incorporation of non-volatile heavy metals into the clinker matrix.

[2] In accordance with the European Court of Justice's judgement of 13 February 2003 delivered in case C-458/00.

21. As highlighted by various authors (for example, Mantus, 1992; Battelle, 2002; WBCSD, 2005; Karstensen, 2007b), the utilisation of hazardous and other wastes in cement manufacturing processes, principally as alternative fuels but also as supplementary raw materials, has numerous potential benefits, including the recovery of the energy content of waste, conservation of non-renewable fossil fuels, reduction of CO_2 emissions, reduction in production costs, and use of an existing technology to treat hazardous wastes.

22. The embodied energy in alternative fuels that is harnessed by cement plants is the most direct benefit, as it replaces demand for fossil fuels (Murray and Price, 2008). By co-processing hazardous and other wastes in a cement kiln and substituting for a non-renewable source, fossil fuel dependency is reduced and savings are made through resource conservation. The amount of fossil fuel demand that is displaced depends, among other factors, on the calorific value and water content of the alternative fuel.

23. Additionally, the fuel substitutes may have lower carbon contents (on a mass basis) than fossil fuels, and alternative raw materials that do not require significantly more heat (and hence fuel) to process, may contribute part of the CaO needed to make clinker from a source other than $CaCO_3$ (Van Oss, 2005). Therefore, another direct benefit of waste co-processing is a potential reduction in CO_2 emissions from cement manufacturing. Moreover, through integrating cement kilns within an overall waste management strategy, co-processing may offer a potential to reduce net global CO_2 emissions relative to a scenario in which waste is combusted in an incinerator without energy recovery (EA, 1999b; CEMBUREAU, 2009).

24. The use of alternative materials to replace the traditional raw materials also reduces the exploitation of natural resources and the environmental footprint of such activities (WBCSD, 2005; CEMBUREAU, 2009).

25. In addition to the aforementioned direct advantages of using hazardous and non-hazardous waste materials for cement manufacturing, there are cost savings derived from the utilisation of pre-existing kiln infrastructure to co-process waste that cannot be minimised or otherwise recycled, thus avoiding the need to invest in purpose-built incinerators or landfill facilities (GTZ/Holcim, 2006; Murray and Price, 2008). Furthermore, unlike with dedicated waste incinerators, when hazardous waste materials are co-processed in cement kilns, ash residues are incorporated into the clinker, so there are no end-products that require further management.

26. The above benefits notwithstanding, it is of utmost importance that co-processing of hazardous waste in cement kilns should only be performed in kilns operated according to best available techniques (BAT) and meeting certain requirements with respect to input, process and emission controls. In this context, it has to be noted that the prevention or minimization of the formation and subsequent release of unintentional persistent organic pollutants (POPs) from cement kilns co-processing hazardous waste is the subject of Article 5 of the Stockholm Convention on Persistent Organic Pollutants, and that relevant guidance on BAT and provisional guidance on best environmental practices (BEP) have been published by the Convention Secretariat. These guidelines were finalized by the Stockholm Convention Expert Group on Best Available Techniques and Best Environmental Practices in December 2006 and were adopted by decision SC-3/5 of the Conference of the Parties at its third meeting, in 2007. Also of particular relevance are the European Commission's BAT reference documents (BREFs) which have been issued for cement, lime and magnesium oxide manufacturing (EIPPCB, 2010), waste treatment industries (EIPPCB, 2006), and on the general principles of monitoring (EIPPCB, 2003). BREFs present the results of an exchange of information, carried out under Council Directive 2008/1/EC (Integrated Pollution Prevention and Control Directive), between European Union (EU) Member States and industries concerned, and offer guidance to EU Member States on BAT and associated emission levels, as well as providing other useful sector specific information.

27. It is also important that an appropriate national legal and regulatory framework, within which hazardous waste management activities can be planned and safely carried out, should be in place to ensure that the waste is properly handled from the point of generation until its disposal, through the operations of segregation, collection, storage, and transportation. Parties to the Basel and Stockholm Conventions should also examine national controls, standards and procedures to ensure that they are in agreement with the conventions and with their obligations under them, including those which pertain to the ESM of hazardous wastes. Co-processing of hazardous waste should only be performed in cement kilns that fully meet permit requirements and follow applicable local regulations. For instance, facilities co-processing hazardous and other wastes that are located in the EU shall need to at least meet the requirements of the Council Directive 2000/76/EC (Waste Incineration Directive) and the Directive 2008/98/EC (Waste Framework Directive).

2.Key Aspects in Co-processing of Hazardous Waste in Cement Kilns

2.1. Principles of Co-processing in Cement Manufacturing

28. Hazardous and non hazardous waste co-processing in cement manufacturing, when carried out in a safe and sound manner, is recognised for far-reaching environmental benefits (CEMBUREAU, 1999a; 2009), however these may be outweighed by poor planning if, for instance, it results in increased pollutant emissions or fails to give priority to a more desirable waste management practice (in terms of the overall environmental outcome). A set of general principles were developed by Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH and Holcim Group Support Ltd. to help avoid the latter scenarios (GTZ/Holcim, 2006). These principles (Table 1) provide a comprehensive yet concise summary of the key considerations for co-processing project planners and stakeholders. The World Business Council for Sustainable Development (WBCSD, 2005) has also outlined similar principles, while Karstensen (2008a, 2009a) has laid out a series of general requirements specific to cement kilns co-processing hazardous wastes on a routine basis. The latter were adopted by the South African Government Department of Environmental Affairs and Tourism (2009) in the framework within which the co-processing in cement production shall be implemented in that country (see Table 2).

Table 1. General principles for co-processing of hazardous and other wastes in cement kilns

Principle	Description
The waste management hierarchy should be respected	– Waste should be co-processed in cement kilns only if there are not more ecologically and economically better ways of recovery – Co-processing should be considered an integrated part of waste management – Co-processing should be in line with the Basel and Stockholm Conventions and other relevant international environmental agreements
Additional emissions and negative impacts on human health must be avoided	– Negative effects of pollution on the environment and human health must be prevented or kept at a minimum – Air emissions from cement kilns co-processing waste cannot be statistically higher than those not co-processing waste
The quality of the cement must remain unchanged	– The product (clinker, cement, concrete) must not be used as a sink for heavy metals – The product must not have any negative impacts on the environment (for example, as determined by leaching tests) – The quality of the product must allow for end-of-life recovery
Companies that co-process must be qualified	– Assure compliance with all laws and regulations – Have good environmental and safety compliance records – Have personnel, processes, and systems in place committed to protecting the environment, health, and safety – Be capable of controlling inputs to the production process – Maintain good relations with public and other actors in local, national and international waste management schemes
Implementation of co-processing must consider national circumstances	– Country specific requirements and needs must be reflected in regulations and procedures – A stepwise implementation allows for the build-up of required capacity and the set-up of institutional arrangements – Introduction of co-processing goes along with other change processes in the waste management sector of a country

Source: GTZ/Holcim (2006)

Table 2. General requirements for co-processing of hazardous and other wastes in cement kilns

(1)	An approved environmental impact assessment and all required national/local licenses, permits, authorisations and permissions;
(2)	Compliance with all relevant national and local regulations;
(3)	Suitable location, technical infrastructure, storage and processing equipment;
(4)	Reliable and adequate power and water supply;
(5)	Application of BAT for emission prevention, control and monitoring, ensuring compliance with regulation and permits, the application of which needs to be verified through regular baseline monitoring.
(6)	Exit gas conditioning/cooling and low temperatures (< 200°C) in the air pollution control device to prevent dioxin formation;
(7)	Clear management and organisational structure with unambiguous responsibilities, reporting lines and feedback mechanism;
(8)	An error reporting system (incident preventive and corrective action) for employees;
(9)	Qualified and skilled employees to manage wastes and health, safety and environmental issues;
(10)	Adequate emergency and safety equipment and procedures, and regular training;
(11)	Authorised and licensed collection, transport and handling of hazardous wastes;
(12)	Safe and sound receiving, storage and feeding of hazardous wastes;
(13)	Adequate laboratory facilities and equipment for hazardous waste acceptance and feeding control;
(14)	Adequate record keeping of wastes and emissions;
(15)	Adequate product quality control routines;
(16)	Implementation and adherence to a recognized environmental management system (EMS) including a continuous improvement programme;
(17)	Independent audits (government sanctioned or otherwise), emission monitoring and reporting;
(18)	Stakeholder dialogues with local community and authorities, and mechanisms for responding to comments and complaints;
(19)	Open disclosure of performance and compliance verification reports on a regular basis.

Source: Adapted from South African Government Department of Environmental Affairs and Tourism (2009) and Karstensen (2009a)

2.2. General Considerations on Environmentally Sound Management

2.2.1 Basel Convention

29. In its Article 2, paragraph 8, the Basel Convention defines ESM of hazardous wastes or other wastes as "taking all practicable steps to ensure that hazardous wastes or other wastes are managed in a manner which will protect human health and the environment against adverse effects which may result from such wastes".

30. In Article 4, paragraph 2 (b), the Convention requires each Party to take the appropriate measures to "ensure the availability of adequate disposal facilities for the environmentally sound management of hazardous or other wastes, that shall be located, to the extent possible, within it, whatever the place of their disposal", while in paragraph 2 (c) it requires each Party to "ensure that persons involved in the management of hazardous wastes or other wastes within it take such steps as are necessary to prevent pollution due to hazardous wastes and other wastes arising from such management and, if such pollution occurs, to minimize the consequences thereof for human health and the environment".

31. Several key principles with respect to ESM of waste were articulated in the 1994 Framework Document on Preparation of Technical Guidelines for the Environmentally Sound Management of Wastes Subject to the Basel Convention.

32. To achieve ESM of wastes, the Framework Document recommends that a number of legal, institutional and technical conditions (ESM criteria) be met, in particular that:

(a) A regulatory and enforcement infrastructure ensures compliance with applicable regulations;

(b) Sites or facilities are authorized and of an adequate standard of technology and pollution control to deal with hazardous wastes in the way proposed, in particular taking into account the level of technology and pollution control in the exporting country;

(c) Operators of sites or facilities at which hazardous wastes are managed are required, as appropriate, to monitor the effects of those activities;

(d) Appropriate action is taken in cases where monitoring gives indications that the management of hazardous wastes has resulted in unacceptable releases; and

(e) People involved in the management of hazardous wastes are capable and adequately trained in their capacity.

33. ESM is also the subject of the 1999 Basel Declaration on Environmentally Sound Management, adopted at the fifth meeting of the Conference of Parties to the Basel Convention. The Declaration calls on the Parties to enhance and strengthen their efforts and cooperation to achieve ESM, including through prevention, minimization, recycling, recovery and disposal of hazardous and other wastes subject to the Basel Convention, taking into account social, technological and economic concerns; and through further reduction of transboundary movements of hazardous and other wastes subject to the Basel Convention.

34. The Declaration states that a number of activities should be carried out in this context, including:

(a) Identification and quantification of the types of waste being produced nationally;

(b) Best practice approach to avoid or minimize the generation of hazardous wastes and reduce their toxicity, such as the use of cleaner production methods or approaches; and

(c) Provision of sites or facilities authorized as environmentally sound to manage wastes and, in particular, hazardous wastes.

2.2.2 Stockholm Convention

35. The term "environmentally sound management" is not defined in the Stockholm Convention. Environmentally sound methods for disposal of wastes consisting of, containing or contaminated with POPs are, however, to be determined by the Conference of Parties in cooperation with the appropriate bodies of the Basel Convention.

2.2.3 Organisation for Economic Co-operation and Development

36. OECD has adopted a recommendation on ESM of wastes which includes various items, inter alia core performance elements of ESM guidelines applying to waste recovery facilities, including elements of performance that precede collection, transport, treatment and storage and also elements subsequent to storage, transport, treatment and disposal of pertinent residues.

37. The core performance elements are:

(a) That the facility should have an applicable environmental management system (EMS) in place;

(b) That the facility should take sufficient measures to safeguard occupational and environmental health and safety;

(c) That the facility should have an adequate monitoring, recording and reporting programme;

(d) That the facility should have an appropriate and adequate training programme for its personnel;

(e) That the facility should have an adequate emergency plan; and

(f) That the facility should have an adequate plan for closure and after-care.

2.3. Considerations for Selection of Wastes for Co-processing

38. The strict quality controls for cement products and the nature of the manufacturing process mean that only carefully selected hazardous and non hazardous waste is suitable for use in co-processing (WBCSD, 2005).

In the BREF issued for this sector by the European Commission BAT is to carry out a careful selection and control of all substances entering the kiln in order to avoid and/or reduce emissions (EIPPCB, 2010).

39. Changes in technology and consumer behaviour also mean that co-processing may not always be the most cost-effective or environmentally preferred way of using a waste stream, because of changes in technology and consumer behaviour (WBCSD, 2005). When deciding on the suitability of a hazardous or non hazardous waste stream for co-processing, besides taking into consideration the chemical composition of the final product (cement) and determining whether the use of the waste will result in damage to the environment or public health and safety, it needs to be ascertained that cost-effective higher-order uses of the material, according to the waste management hierarchy, are not available. Life Cycle Assessment (LCA) is a tool that may assist the decision making process by comparing different waste management scenarios. In assessing recovery operations, the importance of the entire life-cycle approach of hazardous wastes needs to be stressed; the actual recovery process carried out at a facility is only one stage in the recovery chain, and other stages could have adverse environmental effects which may, in some cases, outweigh any benefits of reprocessing the recoverables.

40. As a basic rule, hazardous waste accepted as an alternative fuel and/or raw material should give an added value for the cement kiln in terms of the heating value of the organic part and/or the material value of the mineral part, all the while meeting applicable regulations and permit requirements. Although hazardous and other wastes with a high metal content will generally not be suitable for co-processing, because the operating characteristics of cement plants are variable, the precise composition of acceptable wastes will be dependent upon each plant's ability to handle any particular waste stream. The use of cement kilns as a disposal operation not leading to resource recovery (i.e. for the purpose of destruction or irreversible transformation of hazardous waste constituents), should only be considered if there are environmental benefits to be gained by the kiln operator (for example, NO_x reduction through flame cooling) or it provides a cost-effective and environmentally sound disposal option at the local level.

41. Where cement kilns are used for the destruction of hazardous waste constituents, alternative disposal routes need to be carefully assessed; strict environmental, health and safety standards ought to be met; and the quality of the final product must not be impaired. In countries where stringent requirements for the final product do not exist it is considered more important to require application of BAT and BEP. (UNEP, 2007)

42. Due to the heterogeneous nature of waste, blending and mixing of different hazardous and non hazardous waste streams may be required to guarantee a homogeneous feedstock that meets specifications for use in a cement kiln. However, blending of hazardous wastes should not be conducted with the aim to lower the concentration of hazardous constituents in order to circumvent regulatory requirements. As a general principle, the mixing of wastes must be prevented from leading to the application of an unsuitable (non-environmentally sound) disposal operation (EIPPCB, 2006).

2.3.1 Hazardous wastes suitable for co-processing in cement kilns

43. A wide range of hazardous wastes are amenable to co-processing; however, because cement kiln emissions are site-specific, the decision on what type of waste can be finally used in a certain plant cannot be answered uniformly. The selection of wastes is influenced by many factors other than the nature of the waste itself, or even its hazardous characteristic(s). Consideration needs to be given to kiln operation; raw material and fuel compositions; waste feed points; gas-cleaning process; resulting clinker quality; general environmental impacts; probability of formation and release of POPs; particular waste management problems; regulatory compliance; and public and government acceptance (Van Oss and Padovani, 2003; GTZ/Holcim, 2006; UNEP, 2007; EIPPCB, 2010).

44. The operator should develop a waste evaluation procedure to assess potential impacts on the health and safety of workers and the public, plant emissions, operations and product quality. Some of the variables that should be considered when selecting waste materials include (WBCSD, 2005; UNEP, 2007):

(a) Kiln operation:

- Alkali (sodium, potassium, etc.), sulphur and/or chloride content: Excessive inputs of alkalis, sulphur and/or chlorides may lead to 'build-up' and blockages in the kiln system. Where these compounds cannot be further captured in the cement clinker or kiln dust, a bypass may be required to remove excess alkali, chloride and sulphur compounds from preheater/precalciner kiln systems. In addition, high alkali content may limit recycling of CKD to the operation.

- Heating (calorific) value: The heating value is the key parameter for the energy provided to the process.

- Water content: Overall moisture content may affect productivity and efficiency of the kiln system, and increase the energy consumption; water content of waste therefore needs to be considered in conjunction with that of conventional fuels and/or raw feed materials.

- Ash content: The ash content affects the chemical composition of the cement and may require an adjustment of the composition of the raw mix.

- Exhaust gas flow rate and waste feed rate, to assure sufficient residence time for destruction of organics and to prevent incomplete combustion due to waste overcharging.

- Stability of operation (for example, duration and frequency of CO trips), and the state (liquid, solid), preparation (shredded, milled) and homogeneity of the waste.

(b) Emissions:

- Sulphur content: Sulphur bearing compounds may result in the release of sulphur oxides.

- Organic content: Organic constituents are associated with emissions of CO_2 and may result in emissions of CO and other products of incomplete combustion (PICs) if waste is fed through unsuitable points or during unstable operating conditions.

- Chloride content: These may combine with alkalis to form fine particulate matter composed of chlorides of those alkalis, which can be difficult to control; in some cases, chlorides have combined with ammonia present in the limestone feed to produce highly visible detached plumes of fine particulate composed mainly of ammonium chloride.

- Metals content: The non-volatile behaviour of the majority of heavy metals means that most pass straight through the kiln system and leave as a constituent of the clinker. Volatile metals introduced into the kiln will be in part internally recycled by evaporation and condensation processes, if not emitted in the exhaust gas of the kiln, and build-up within the kiln system until equilibrium is reached and maintained. Thallium, mercury and their compounds are easily volatilized and to a lesser extent so are cadmium, lead, selenium and their compounds. Dust control devices can only capture the particle-bound fraction of heavy metals and their compounds, which needs to be taken into account when wastes containing volatile metals are co-processed. Wood treated with CCA (copper, chromium, arsenic) preservatives also requires special consideration with regard to the efficiency of the exhaust gas cleaning system. Mercury is a highly volatile metal, which, depending on the exhaust gas temperature, is present in particle-borne and/or vapour form in the air pollution control equipment (EIPPCB, 2010).

- Alkali bypass exhaust gas: At facilities equipped with an alkali bypass, the alkali bypass gases can be released either from a separate exhaust stack or from the main kiln stack. According to U.S. EPA (1998) it is expected that the same hazardous air pollutants (HAPs) found in the main stack are found in the alkali bypass stack. Where an alkali bypass system is installed, appropriate control of the exhaust to atmosphere also needs to be provided on the bypass exhaust similar to that mandated for the main exhaust stack (UNEP, 2007).

(c) Clinker, cement and final product quality:

- Phosphate content: Elevated levels of phosphates may retard setting time.

- Fluorine content: Elevated levels of fluorine affect setting time and strength development.

- Chlorine, sulphur, and alkali content: Elevated levels of alkali, chloride or sulphur compounds may affect overall product quality.

- Thallium and chromium content: These affect cement quality and may cause allergic reactions in sensitive users. The leachability of chromium from concrete debris may be higher than that of other metals (Van der Sloot et al., 2008). Limestone, sand and, in particular, clay, contain chromium, therefore its content in cement is not only unavoidable but also considerably variable[3]. The Norwegian National Institute of Occupational Health (Kjuus et al., 2003) reviewed several studies of chromate allergy in humans, especially those involving construction workers, and in its assessment the Institute says that the main sources of chromium in finished cement are the raw materials, refractory bricks in the kiln and chromium steel grinders, the relative contribution of which may vary, depending on the chromium content of the raw materials and on the manufacturing conditions. Minor sources include fuels, both conventional and alternative (EIPPCB, 2010). Cement eczema may be caused either by exposure to wet cement and high pH which induces irritant contact dermatitis, or by an immunological reaction to chromium which elicits allergic contact dermatitis (Kjuus et al., 2003). For uses where there is a possibility of contact with the skin, cement and cement-containing preparations may not be used or placed on the market in the European Union, if they contain, when hydrated, more than 0,0002 percent soluble chromium (VI) of the total dry weight of the cement[4]. As the main chromate source is the raw material, to reduce the levels of chromium (VI) in cement a reducing agent needs to be added to the finished product; the main reducing agents used in Europe being ferrous sulphate and tin sulphate (EIPPCB, 2010).

– Leachable trace elements: Heavy metals are present in all feed materials, conventional and otherwise, however under certain test conditions, leached concentrations from concrete of other metals besides chromium (aluminium and barium for instance) may approach drinking water standards (GTZ/Holcim, 2006).

45. Only waste of known composition and known energy and/or mineral value is suitable for co-processing in cement kilns. Moreover, plant-specific health and safety concerns need to be addressed as well as due consideration given to the waste management hierarchy (as a general principle). Co-processing should only be applied if not just one but all tangible preconditions and requirements of environmental, health and safety, socio-economic and operational criteria are fulfilled (UNEP, 2007). As a consequence not all waste materials are suitable for co-processing.

46. As per the guidelines on BAT and provisional guidance on BEP published by the Secretariat of the Stockholm Convention on POPs, the following wastes are not recommended for co-processing in cement kilns (UNEP, 2007), however individual facilities may also exclude other wastes outside the list below depending on local circumstances.:

– Radioactive, or nuclear, waste;

– Electric and electronic waste (e-waste);

– Whole batteries;

– Corrosive waste, including mineral acids;

– Explosives;

– Cyanide bearing waste;

– Asbestos-containing waste;

– Infectious medical waste;

– Chemical or biological weapons destined to destruction;

– Mercury waste; and

– Waste of unknown or unpredictable composition, including unsorted municipal waste.

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[3] Trace element concentrations in conventional raw materials are provided in Annex 2 for information purposes.

[4] Directive 2003/53/EC of the European Parliament and of the Council, of 18 June 2003, Amending for the 26th Time Council Directive 76/769/EEC Relating to Restrictions on the Marketing and Use of Certain Dangerous Substances and Preparations (Nonylphenol, Nonylphenol Ethoxylate and Cement).

47. Cement plants are not designed or operated to meet safety and health requirements for radioactive waste management, for which the preferred approach is concentration (reduction of volume) and containment of radionuclides by means of a conditioning process to prevent or substantially reduce dispersion in the environment.

48. Electric and electronic waste contains valuable resources such as precious metals and recycling should be the preferred option. Co-processing of plastic parts from end-of-life electronics might be an option after appropriate disassembly and sorting.

49. Co-processing of batteries would lead to undesirable concentrations of pollutants in the cement and air emissions. Moreover, batteries contain valuable resources such as lead and recycling should be the preferred waste management option.

50. Corrosive wastes may cause corrosion and fouling problems in equipment not specifically designed for this type of waste (this being usually the case with pre-processing, storage and injection systems). Wastes with high chlorine and sulphur contents, such as some mineral acids, may also have a negative impact on the clinker production process or may affect product quality. Additionally, high sulphur contents may result in the release of sulphur oxides (UNEP, 2007).

51. Explosive waste should not be co-processed because explosive reactions in the cement kiln would have a negative impact on process stability. There are also occupational safety concerns due to the risk of uncontrolled explosions during transport and pre-processing activities.

52. The high volatility of mercury in cement kilns poses a problem regarding air emissions, therefore inputs to the kiln of wastes consisting of, containing or contaminated with mercury need to be controlled and kept to the minimum possible. Since limiting the amount of mercury in the waste to be fed in the kiln does not by itself assure low mercury air emissions, an emission limit value for mercury needs to be in place.

2.3.2 Waste recovery or final disposal in cement kilns

53. Selected waste streams with recoverable energy value can be used as fuels in a cement kiln, replacing a portion of conventional fuels, if they meet specifications. Similarly, selected waste streams containing useful components such as calcium, silica, alumina, and iron can be used as raw materials in the kiln, replacing raw materials such as clay, shale, and limestone. Some wastes will meet both of these requirements and will be suitable for processing for energy recovery and for materials recovery or as an ingredient.

54. Conversely, waste combustion in a cement kiln without any substitution, solely for the purpose of destruction or irreversible transformation of hazardous waste constituents, should not be considered a recovery operation[5].

55. To distinguish between operations that lead to resource recovery and those that do not, specific criteria may need to be developed to evaluate the contribution of the waste to the production process. The general decision-making process is outlined in Figure 2. To this respect, some approaches have been proposed that consider, for example, either the higher or the lower heating value of the waste to assess its energy value, and the

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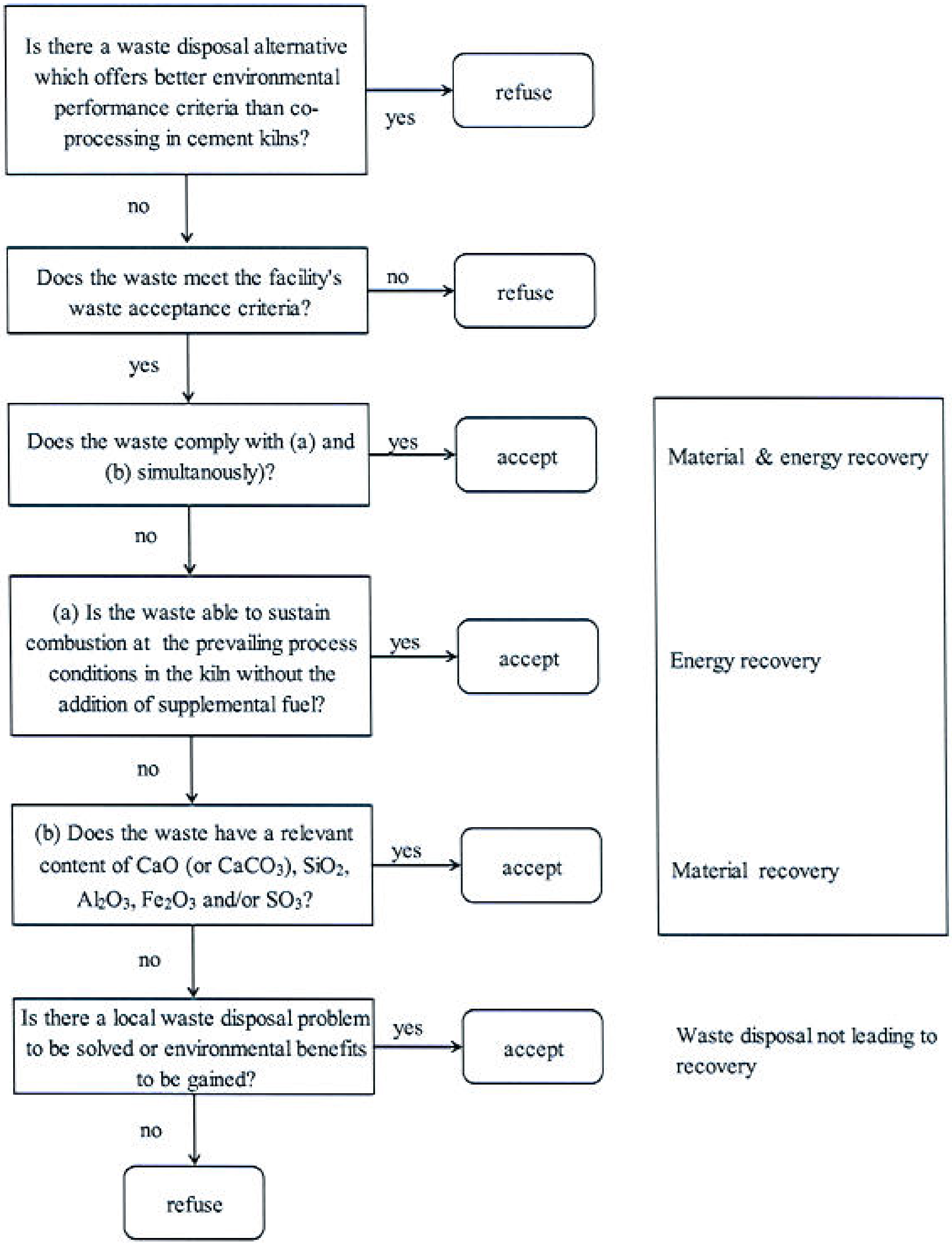
[5] Under the Basel Convention the term "disposal" is used to refer to operations listed in both Annex IV.A (operations which do not lead to the possibility of resource recovery, recycling, reclamation, direct re-use or alternative uses) and Annex IV.B (operations which may lead to resource recovery). The former category involves final disposal and includes operations like deposit into landfills, land treatment, deep injection, surface impoundment, release into a water body, biological treatment, physico-chemical treatment, incineration, and temporary or permanent storage. The latter category involves recovery operations and includes use as fuel (other than in direct incineration), solvent reclamation, recycling, recovery of components used for pollution abatement or from catalysts, used oil refining, and land treatment resulting in benefit to agriculture or ecological improvement. However, in some countries, disposal refers only to the operations specified in annex IV A, that is, to such operations which do not lead to any form of recovery.

The term "destruction" is not explicitly defined in the Basel Convention and is not listed as a disposal option under annex IV A. However, it might be considered a subset of those activities included under the definition of disposal. This subset could include activities where the waste is almost completely eliminated through physico-chemical or biological treatment, through incineration or through other means. The Basel Convention includes such activities within its definition of disposal. (UNEP, 1999) material's chemical composition (ash, CaO or $CaCO_3$, SiO_2, Al_2O_3, Fe_2O_3, SO_3, and/or water) to assess its mineral value (Zeevalkink, 1997; Koppejan and Zeevalkink, 2002; GTZ/Holcim, 2006). An example is provided in Annex 2.

56. Although wastes without, for all practical purposes, energy or mineral value should not be considered for co-processing, the high temperatures, long residence times, and oxidizing conditions provided by cement kilns, make it possible, at the request of national or local governments, for the kilns to be used for the purpose of destruction or irreversible transformation of hazardous waste constituents in particularly problematic waste streams such as obsolete pesticide stocks. However, this is an activity that, being distinct from fuel or raw material substitution in the process, is outside the scope of co-processing and needs to be assessed on a case-by-case basis as well as agreed upon jointly by regulatory authorities and operators. Trial burns may need to be conducted to demonstrate that performance criteria are met.

57. It should be noted that cement kilns are primarily production processes for clinker, and not all operating conditions that may produce satisfactory clinker product are ideal for the destruction of wastes; for example, cement kilns tend to operate at lower exhaust oxygen levels and more elevated carbon monoxide levels than well operated incinerators. Destruction of organic wastes requires not only high temperature and long residence time, but also the availability of adequate oxygen and sufficient mixing between the organic compounds intended for destruction and the oxygen. Conditions can arise where wastes are not destroyed adequately if waste is not introduced properly to the kiln or available oxygen levels are too low. Good design and operation are critical to the use of cement kilns for this application. (UNEP, 2007)

Figure 2. Waste acceptance decision process



2.3.3 Destruction efficiency of hazardous organic constituents

58. To verify the ability of a facility to efficiently destroy organic pollutants in an irreversible and sound way, the destruction and removal efficiency (DRE) or destruction efficiency (DE) should be determined, as demonstrated in a trial burn. The trial burn involves selecting a principal organic hazardous constituent (POHC) in the waste feed, and sampling and analysis to determine input and emission rates of the same POHC. A trial burn typically consists of a series of tests (one for each set of operating conditions for which the facility desires to be permitted), and there are usually three runs performed for each test.

59. Trial burns are recommended to demonstrate destruction of wastes consisting of, containing or contaminated with POPs. Trial burns with hazardous wastes require professional supervision and independent verification (Karstensen, 2008a). Prior to a trial burn, the operator should demonstrate to the satisfaction of the competent authorities that the baseline operation is properly controlled and that there are safeguards against potential environmentally damaging abnormal operations. To this end it is recommended that the general requirements set out in Table 2 be thoroughly considered.

60. During the trial burn, operating limits are established for parameters that may adversely affect the attainment of the demonstrated DRE or DE during routine operations, namely maximum hazardous waste feed and maximum kiln production rate (Karstensen, 2009b). Subsequent to the trial burn, permit limits are established for these parameters.

61. The potential use of cement kilns to thermally destroy polychlorinated biphenyls (PCBs) has been investigated in many countries. The DREs determined from several trial burns indicate that well-designed and operated cement kilns are effective at destroying PCBs. A DRE of 99.9999 percent is required by several jurisdictions for PCBs (for example, under the United States Toxic Substances Control Act, TSCA), which could be used as an indicative BAT standard. (UNEP, 2007)

62. A cement kiln should demonstrate that it is capable of destroying (through combustion) or removing (through settling in ductwork or capture in air pollution control devices) at least 99.9999 percent of targeted POPs (for non-POPs contaminants a DRE of 99.99 percent needs to be demonstrated). Moreover, a PCDDs/PCDFs emission limit of 0.1 ng TEQ/Nm^3 [6] should be met under testing conditions (SBC, 2007). The cement kiln should also comply with existing emission limit values.

63. An alternative approach to trial burns under worst-case conditions, that is considered to provide the same qualitative information, has been proposed by Karstensen (2009b). This involves conducting a baseline emissions study (no hazardous waste fed to the kiln) and one test run to obtain destruction performance and pollutant emissions data while feeding hazardous waste into the kiln; both tests conducted under normal operating conditions, all the while meeting an emissions limit for PCDDs/PCDFs of 0.1 ng TEQ/Nm^3 as well as meeting other regulatory requirements. This approach for performance verification, together with adequate safety arrangements, input control and operational procedures, is thought to secure the same level of environmental protection as current regulation in the European Union (GTZ/Holcim, 2006). This approach was used to demonstrate a DRE of 99.9999969 percent for fenobucarb and 99.9999832 percent for fipronil in a cement kiln in Vietnam (Karstensen et al., 2006).

64. A compilation of performance verification and test burns results is provided in Annex 3.

2.4. Quality Assurance/Quality Control

65. A comprehensive quality assurance (QA) and quality control (QC) programme is necessary to ensure that the product meets standard specifications, that plant operations are not negatively affected by the use of hazardous wastes, to protect the environment and to reduce risks to worker health and safety. QA is necessary for ensuring that all data and the decisions based on that data are technically sound, statistically valid, and properly documented.

66. A QA plan would need to be prepared to help ensure that the monitoring, sampling, and analytical data meet specific objectives for precision, accuracy, and completeness, and to provide the framework for evaluating data quality. The plan would need to encompass all materials handled at the facility (waste streams and product), and should give detailed instructions for the following:

- Organization and responsibilities;
- QA objectives for measurement data in terms of precision, accuracy, completeness, representativeness, and comparability;
- Sampling procedures;

[6] Dry basis, corrected to 11 percent O_2, 101.3 kPa and 273.15 K.

- Sample handling and custody;
- Analytical procedures;
- QC checks (blanks, spikes, replicates, etc.) and frequency;
- Instrument/equipment testing, inspection, or maintenance;
- Instrument/equipment calibration procedures and frequency; and
- Data review, verification, validation, and reporting.

67. Adequate laboratory design, infrastructure, equipment, and instrumentation ought to be provided and maintained to ensure that all required analysis are completed in a timely manner. Periodic interlaboratory tests would need to be considered in order to evaluate and improve laboratory performance.

68. Safety and health considerations should be taken into consideration when conducting sampling. Employees who perform sampling activities need to be properly trained with respect to the hazards associated with waste materials, as well as with any waste handling procedures that will assist in protecting the health and safety of the sampler. In addition, the employees ought to be trained in the proper protective clothing and equipment that must be used when performing sampling activities. All persons involved in sampling activities should be fully aware of applicable QA/QC procedures.

69. As regards BAT for waste quality control in cement manufacturing processes, the following have been identified by the EIPPCB (2010):

- To apply QA systems to guarantee the characteristics of wastes and to analyse any waste that is to be used as raw material and/or fuel in a cement kiln for: maintenance of quality over time; physical criteria, for example, emissions formation, coarseness, reactivity, burnability, calorific value; chemical criteria, for example, chlorine, sulphur, alkali and phosphate content and relevant metals content;
- To control the amount of relevant parameters for any waste that is to be used as raw material and/or fuel in a cement kiln, such as chlorine, relevant metals (for example, cadmium, mercury, thallium), sulphur, total halogen content; and
- To apply QA systems for each waste load.

70. Internal audits carried out with sufficient frequency would ensure that QA/QC procedures are in use and that personnel conform to these procedures. Independent third party audits ought to be conducted at least once a year or as required to determine the effectiveness of the implemented quality system. Audit reports should be submitted to management with requirements for a plan to correct observed deficiencies.

2.5. Health and Safety Aspects

71. The protection of health and safety during hazardous waste activities needs to be integrated into all aspects of facility operations, and should be a conscious priority for all involved, from corporate management to the most recently hired employee. Overall and specific personnel requirements, the chain of command, and individual roles and responsibilities, ought to be clearly established.

72. A health and safety programme should be designed to identify, evaluate, and control safety and health hazards, and provide for emergency response for hazardous waste operations. The content and extent of this programme ought to be proportionate to the types and degrees of hazards and risks associated with specific operations.

73. Adequate documentation and information on safe hazardous waste handling, operating procedures and emergency contingency measures are mandatory. Facility management staff must ensure an informed workforce through openness and transparency about health and safety measures and standards. Safety and emergency instructions need to be provided to employees and contractors in due time, and should be easily understandable.

74. In the EU, the BAT conclusion for the safety management for the use of hazardous waste is to apply safety management for the handling, for example, storage, and/or feeding of hazardous waste materials, such as using a risk based approach according to the source and type of waste, for the labelling, checking, sampling and testing of waste to be handled. (EIPPCB, 2010)

2.5.1 Hazard analysis

75. The hazards and potential exposures affecting facility employees ought to be determined to ensure that appropriate control practices and techniques are in place to maintain worker health and safety, and identify hazards present that would require the use of personal protective equipment (PPE). To this end, techniques such as job hazard analysis (JHA), job safety analysis (JSA), safety analysis reports (SAR), process hazard analysis (PHA), and job, task, and hazard analysis (JTHA), are recommended.

2.5.2 Access and hazard control

76. To eliminate or control worker exposure to hazards, the following have to be considered (in order of preference):

- Engineering controls, to preclude worker exposure by removing or isolating the hazard (for example, ventilation or use of remotely operated material handling equipment);
- Administrative controls, to manage worker access to hazards or establish safe work procedures (for example, security measures to prevent unauthorized or unprotected access to hazardous wastes on-site); and
- PPE, when engineering or administrative controls are not feasible or do not totally eliminate the hazard.

77. The use of an appropriate combination of the above would reduce and maintain employee exposure to or below national occupational exposure limit values, or, if these are not available, below published exposure levels, examples of which include: the Threshold Limit Value (TLV) occupational exposure guidelines published by American Conference of Governmental Industrial Hygienists (ACGIH); the Pocket Guide to Chemical Hazards published by the United States National Institute for Occupational Health and Safety (NIOSH); Permissible Exposure Limits (PELs) published by the Occupational Safety and Health Administration of the United States (OSHA); Indicative Occupational Exposure Limit Values (IOELVs) published by European Union member states, or other similar sources.

78. For hazardous substances and health hazards for which there is no permissible exposure limit or published exposure limit, the operator could use the published literature and material safety data sheets (MSDS) as a guide in making the determination as to what level of protection is appropriate.

2.5.3 Personal protective equipment

79. Employees, contractors and individuals visiting the installation, need to be provided with and required to use PPE where engineering control methods are infeasible to reduce exposure to or below the permissible exposure limits. PPE should be selected to protect against any hazard that is present or likely to be present and should be appropriate to the task-specific conditions and duration.

80. An explanation of equipment selection and use, maintenance and storage, decontamination and disposal, training and proper fit, donning and doffing procedures, inspection, in-use monitoring, programme evaluation, and equipment limitations, ought to be provided to all personnel involved in hazardous waste operations.

2.5.4 Training

81. Effective training is one of the most important keys to worker safety and health. Employees should be trained to a level required by their job function and responsibility before they are permitted to engage in hazardous waste operations that could expose them to hazardous substances, safety, or health hazards. Training activities should be adequately monitored and documented (curriculum, duration, and participants).

82. The training should cover safety, health and other hazards present on the facility; use of personal protective equipment; work practices by which the employee can minimize risks from hazards; safe use of engineering controls and equipment on the site; and, medical surveillance requirements including recognition of symptoms and signs which might indicate over exposure to hazards. Employees who are engaged in responding to hazardous emergency situations should also be trained in how to respond to such expected emergencies.

2.5.5 Medical surveillance

83. A medical monitoring programme should be implemented to assess and monitor employee health both prior to employment and during the course of work, to provide emergency and other treatment as needed. An effective programme should consider at least the following components:

- Pre-employment screening, to determine fitness-for-duty, including the ability to work while wearing PPE, and provide baseline data for future exposures;
- Periodic medical monitoring examinations (the content and frequency of which would depend on the nature of the work and exposure), to determine biological trends that may mark early signs of chronic adverse health effects; and
- Provisions for emergency treatment and acute non-emergency treatment.

2.5.6 Emergency response

84. Emergency preparedness should be established for the protection of the workforce and public before hazardous waste operations can begin. An Emergency Response Plan should be in place to ensure that appropriate measures are taken to handle possible on-site emergencies and coordinate off-site response. At minimum, this plan should address the following:

- Pre-emergency planning and coordination with outside emergency responders;
- Personnel roles, lines of authority, training and communication procedures;
- Emergency recognition and prevention procedures;
- Safe distances and places of refuge;
- Site security and control procedures;
- Evacuation routes and procedures;
- Site mapping highlighting hazardous areas, site terrain, site accessibility and off-site populations or environments at potential risk;
- Decontamination procedures;
- Emergency medical treatment and first aid procedures;
- Personal protective and emergency equipment at the facility;
- Emergency alerting and response procedures;
- Documenting and reporting to local authorities; and
- Critique of response and follow-up procedures.

85. Emergency equipment, such as fire extinguishers, self-contained breathing apparatus, sorbents and spill kits, and shower/eye wash stations should be located in the immediate vicinity of the hazardous waste storage and processing areas.

86. The Plan requirements should be rehearsed regularly using drills and mock situations, and reviewed periodically in response to new or changing facility conditions or information.

87. Arrangements should be made to familiarize local authorities and emergency responders with the layout of the facility; properties of hazardous waste handled at the facility and associated hazards; places where facility personnel would normally be working; facility entrances and possible evacuation routes. Arrangements agreed to by local authorities, hospitals and emergency response teams should be described in the Emergency Response Plan.

2.6. Communications and Stakeholder Involvement

88. Stakeholders are all the individuals and groups who see themselves as potentially affected by the operations of a facility, whether on a local, national, or international scale. These include, but are not limited to, neighbours, community organizations, employees, trade unions, government agencies, the media, non-governmental organizations (NGOs), contractors, suppliers, and investors.

89. Public communication means providing information through any media, including brochures, websites, newspapers, radio and television. Stakeholder involvement means listening directly to community members and others with an interest in the facility, through public meetings, presentations, advisory committees, and personal conversations.

90. Communication and stakeholder involvement should occur as part of the normal operations of a plant. Facilities need to be clear about their objectives for working with stakeholders, have a reasonable timescale for engagement, commit the necessary resources, and be prepared to work with stakeholders to find mutually beneficial outcomes. Detail on how to design and develop a communications and stakeholder involvement plan is provided by U.S. EPA (1996), Hund et al. (2002), and The Environment Council (2007), among others.

91. Operators and regulatory authorities should be prepared to address public concerns over possible impacts of co-processing, and they should strive to establish efficient communication processes in order to explain the activities. Operators planning to handle and/or co-process hazardous waste should provide all necessary information to allow stakeholders to understand the purpose of the use of such wastes in the cement kiln, and to make them aware of the measures that will be implemented to avoid adverse impacts on the public and the environment.

3.Waste Acceptance and Pre-processing

3.1. Introduction

92. Due to the heterogeneous nature of waste, co-processing in cement kilns generally requires some degree of waste processing to produce a relatively uniform waste stream that complies with the technical and administrative requirements of cement manufacture and to guarantee that environmental standards are met[7]. However in some instances, as is for example the case of used oil or tyres, wastes may be used 'as-delivered' and without further processing.

93. With any process, the quality of what goes in determines the quality of what comes out. Therefore, attention should be paid to the selection of suitable waste materials, whether they are collected directly from the generators or through intermediaries. Operators need to ensure that only hazardous waste originating from trustworthy parties will be accepted (with deliveries of unsuitable wastes refused), considering the integrity of all participants throughout the supply chain. Only qualified, authorized and licensed transport companies should be used, otherwise, serious accidents and incidents may arise due to incompatible, poorly labelled or poorly characterised wastes being mixed or stored together.

94. The following recommendations provide only general indications on the management of wastes, in particular hazardous wastes. Specific handling requirements shall need to be identified on the basis of the chemical and biological characteristics of individual waste streams, environmental and health effects, the safety of personnel, and compliance with permitting requirements and local regulations.

3.2. Waste Acceptance

95. Knowledge of wastes, before they are accepted and processed, is necessary to enable the operator to ensure that the waste is within the requirements of the facility's permit and will not adversely affect the process. Generators of hazardous waste should, in most circumstances, be best placed to know the composition, nature and problems associated with their waste and should ensure that all information concerning it is passed to those involved in its subsequent management. However, sometimes the generator of the waste may wrongly consider a waste as non-hazardous, or the constituent present at greatest concentration may be used to describe the waste although this may not be the constituent which has the potential to be most hazardous or cause most harm.

96. Hazardous and non hazardous waste acceptance comprises two stages: pre-acceptance (or screening) and on-site acceptance. Pre-acceptance involves the provision, as necessary, of information and representative samples of the waste to allow operators to determine the suitability of the waste before arrangements are in place to accept the waste. The second stage involves acceptance procedures when the waste arrives at the facility to confirm the characteristics of waste previously approved.

97. Failure to adequately screen waste samples prior to acceptance and to confirm its composition on arrival at the installation may lead to subsequent problems, including an inappropriate storage and mixing of incompatible substances, and accumulation of wastes.

3.2.1 Pre-acceptance

98. A pre-acceptance (or pre-shipment screening) protocol should be designed to ensure that only hazardous waste streams that can be properly and safely handled are approved for shipment to the facility. Such protocol is necessary to:

- Ensure regulatory compliance by screening out unsuitable wastes;
- Confirm the details relating to composition, and identify verification parameters that can be used to test waste arriving at the facility;

[7] Pre-processing should be carried out because it is a technical requirement from the kiln operator to guarantee a homogeneous and stable feedstock and not to circumvent waste acceptance procedures.

- Identify any substances within the waste that may affect its processing, or react with other reagents; and

- Accurately define the range of hazards exhibited by the waste.

99. The operator should obtain information on the nature of the process producing the waste, including the variability of this process; an appropriate description of the waste regarding its composition (chemicals present and individual concentrations), handling requirements and associated hazards; the quantity of waste; the form the waste takes (solid, liquid, sludge etc); and, sample storage and preservation techniques. Where possible, the information should be provided by waste generators themselves, otherwise a system for the verification of the information provided by any intermediaries should be considered.

100. A system for the provision and analysis of a representative sample(s) of the waste should be in place. The waste sample should be taken by a person who is technically competent to undertake the sampling process, and analysis should be carried out by a laboratory (preferably accredited) with robust QA/QC methods and record keeping; a chain-of-custody procedure should be considered. The operator should ensure that, for each new waste, a comprehensive characterisation (profiling) and testing with respect to the planned processing, is undertaken. No wastes should be accepted at the facility without sampling and testing being carried out, with the exception of unused, outdated or off-specification products which have not been subsequently contaminated (and for which appropriate MSDS or product data sheets are available).

101. A Waste Analysis Plan (WAP) should be prepared and maintained documenting the procedures that should be used to obtain a representative sample of a waste and to conduct a detailed chemical and physical analysis of this representative sample. A WAP should address measures to identify potentially reactive, and incompatible wastes[8]. The WAP should comprise testing of a representative sample of waste to qualify it for use at the facility (for waste pre-acceptance purposes); testing of incoming waste shipments to verify its constituents (for waste acceptance purposes); and testing of samples taken during or after waste pre-processing or blending to verify the quality of the resultant stream.

102. Operators should ensure that the technical appraisal is carried out by suitably qualified and experienced staff who understand the capabilities of the facility.

103. Records relating to the pre-acceptance should be maintained at the facility for cross-referencing and verification at the waste acceptance stage. The information should be recorded and referenced to the waste stream so that it is available at all times. The information must be regularly reviewed and kept up to date with any changes to the waste stream.

3.2.2 On-site acceptance

104. On-site verification and testing should take place to confirm the characteristics of the waste, and the consistency with the pre-acceptance information. Acceptance procedures should address:

- Measures to deal with pre-approved wastes arriving on-site, such as a pre-booking system to ensure that sufficient capacity is available;

- Vehicle waiting and traffic control;

- Procedures for checking paperwork arriving with the load;

- Procedures for load inspection, sampling and testing;

- Criteria for the rejection of wastes and the reporting of all non-conformances;

- Record keeping; and

- Procedures for periodic review of pre-acceptance information.

[8] The U.S. EPA document, "A Method of Determining the Compatibility of Hazardous Wastes" (EPA-600/2-80-076), contains procedures to evaluate qualitatively the compatibility of various categories of wastes.

105. Wastes should not be accepted without detailed written information identifying the source, composition and hazard of the waste.

106. Where facilities provide a service to emergency services such as the removal of spillages or fly-tipped hazardous wastes, there may be situations where the operator is unable to adhere to established pre-acceptance and/or acceptance procedures. In such instances, the operator should communicate the occurrence to the competent authorities immediately.

3.2.2.1. Arrival

107. Hazardous wastes should be received under the supervision of a suitably qualified and trained person, and only if sufficient storage capacity exists and the site is adequately manned. All wastes received at the facility should initially be treated as being unknown and hazardous until compliance with specifications has been positively verified.

108. Hazardous waste delivery should accompanied by a suitable description of the waste, including name and address of the generator; name and address of the transporter; waste classification/description; volume/weight; and hazard(s) of the waste (such as, flammability, reactivity, toxicity or corrosivity). Documentation accompanying the shipment should be reviewed and approved (including the hazardous waste manifest documentation, if applicable), and any discrepancies should be resolved before the waste is accepted. If discrepancies cannot be resolved, the shipment should be rejected back to the original generator, or at his request, to an alternate facility.

109. Where possible, waste loads should be visually inspected. Containers should be checked to confirm quantities against accompanying paperwork. Containers should be clearly labelled in accordance with applicable regulations for the transport of dangerous goods and should be equipped with well-fitting lids, caps and valves secure and in place. Drums and containers should be inspected for leaks, holes, and rust. Any damaged, corroded or unlabelled drum should be classified as 'non-conforming' and dealt with appropriately.

110. All incoming loads should be weighed, unless alternative reliable volumetric systems linked to specific gravity data are available.

3.2.2.2. Inspection

111. Wastes should not be accepted at the facility without thorough inspection being carried out. Reliance solely on written information supplied should not be acceptable, and physical verification and analytical confirmation should be required to the extent necessary to verify that it meets permit specifications and regulatory requirements. All hazardous wastes and other wastes, whether for processing or simply storage, should be sampled and undergo verification and testing, according to the frequency and protocol defined in the WAP (except unused, outdated or off-specification products which have not been subsequently contaminated).

112. On-site verification and testing should take place to confirm:

- The identity and description of the waste;
- Consistency with pre-acceptance information; and
- Compliance with the facility permit.

113. Techniques for inspection vary from simple visual assessment to full chemical analysis. The extent of the procedures adopted will depend upon waste chemical and physical composition and variation; known difficulties with certain waste types or of a certain origin; specific sensitivities of the installation concerned (for example, certain substances known to cause operational difficulties); and the existence or absence of a quality controlled specification for the waste, among others. (Karstensen, 2008a)

114. The facility should have a designated sampling or reception area. Containerised waste should be unloaded in this area, only if adequate space is available, and temporarily stored pending further inspection (sampling and sample analysis); wastes should be segregated immediately to remove possible hazards due to incompatibility. Sampling should be performed at the earliest possible time, preferably no later than 24 hours after unloading. During this period, hazardous wastes should not be bulked, blended or otherwise mixed. Bulk wastes should be inspected and accepted for processing prior to unloading.

115. Sampling should comply with specific national legislation, where it exists, or with international standards. Sampling should be directly supervised by laboratory staff, and in countries where regulations do not exist, qualified staff should be appointed. Sampling procedures should include well-established procedures such

as those developed by the American Society for Testing and Materials (ASTM), the European Committee for Standardization (CEN), and/or the United States Environmental Protection Agency (EPA). A record of the sampling regime for each load and justification for the selected option should be maintained at the installation.

116. Samples should be analysed by a laboratory with a robust QA/QC programme, including but not limited to suitable record keeping and independent assessments. Analysis should be carried out at the speed required by facility procedures, which, particularly for hazardous wastes, often means that the laboratory needs to be on-site.

117. Typically, hazardous and non hazardous waste shipments are sampled and analyzed for a few key chemical and physical parameters (fingerprint analysis) to substantiate the waste composition designated on the accompanying paperwork (manifest and/or other shipping paper). The selection of key parameters must be based on sufficient waste profile knowledge and testing data to ensure accurate waste representation. When selecting fingerprint parameters, consideration should be given to those parameters that can be used to: identify wastes that are not permitted; determine whether the wastes are within the facility's operational acceptance limits; identify the potential reactivity or incompatibility of the wastes; and indicate any changes in waste composition that may have occurred during transportation or storage. Should the results of the fingerprint testing of a given waste stream fall outside the established tolerance limits, the waste may be re-evaluated for possible acceptance to prevent the unnecessary movement of waste back and forth between the generator and the installation when waste can be managed by the facility. Re-evaluation should consider facility conditions for storage and processing; additional parameter analyses performed as deemed appropriate by the operator (and established in the WAP); and permit requirements.

118. The inspection scheme may include (Karstensen, 2008a): assessment of combustion parameters; blending tests on liquid wastes prior to storage; control of flashpoint; and screening of waste input for elemental composition, for example by ICP, XRF and/or other appropriate techniques, in accordance to waste types and characteristics, and the facility waste acceptance criteria.

119. Wastes should be moved to the storage area only after its acceptance. Should the inspection or analysis indicate that the wastes fail to meet the acceptance criteria (including damaged or unlabelled drums), then such loads should be stored in a dedicated area allocated for non-conforming waste storage (quarantine area), and dealt with appropriately.

120. All areas where hazardous waste is handled should have an impervious surface with a sealed drainage system. Attention should be given to ensuring that incompatible substances do not come into contact resulting from spills from sampling, for example, within a sump serving the sampling point. Absorbents should be made available.

121. Suitable provisions, in accordance with national legislation and practice, should be made to verify that wastes being received at the facility are not radioactive. Plastic scintillation detectors are one type of detector used.

122. After being accepted for processing, hazardous containerised waste should be labelled with the date of arrival on-site and primary hazard class. Where containers are bulked, the earliest date of arrival of the bulked wastes should be transposed from the original container onto the bulk container. A unique reference number should be applied to each container for the purpose of the in-plant waste tracking system.

3.2.3 Non-conforming waste

123. The operator should have clear and unambiguous criteria for the rejection of wastes (including wastes that fail to meet the acceptance criteria, and damaged, corroded or unlabelled drums), together with a written procedure for tracking and reporting such non-conformance. This should include notification to the customer/waste generator and competent authorities.

124. The operator should also have a clear and unambiguous policy for the subsequent storage (including a maximum storage volume) and disposal of such rejected wastes. This policy should achieve the following:

- Identify the hazards posed by the rejected wastes;
- Label rejected wastes with all information necessary to allow proper storage and segregation arrangements to be put in place; and
- Segregate and store rejected wastes safely pending removal within a reasonable time (where possible, no more than five working days).

125. Wastes that do not fulfil the acceptance criteria of the plant should be sent back to the waste generator, unless an agreement is reached with the generator to ship the rejected waste to an alternative authorised destination.

3.2.4 In-plant tracking system

126. An internal tracking system and stock control procedure should be in place for all wastes, beginning at the pre-acceptance stage, to guarantee the traceability of waste processing and to enable the operator to:

- Prepare the most appropriate waste blend;
- Prevent unwanted or unexpected reactions;
- Ensure that the emissions are either prevented or reduced; and
- Manage the throughput of wastes.

127. The tracking system (which may be a paper system, an electronic system, or a combination of both), should 'follow' the waste during its acceptance, storage, processing and removal off-site. It should consequently be possible at any time for the operator to identify where a specific waste is on the facility, and the length of time it has been there. Records should be held in an area well removed from hazardous activities to ensure their accessibility during any emergency.

128. Once a waste has entered bulk storage or a treatment process, the tracking of individual wastes will not be feasible. However, records should be maintained to ensure sufficient knowledge is available as to what wastes have entered a particular tank, storage pit or other enclosure. For example, it is necessary to keep track of residues that will be building up within a vessel between de-sludging events in order to avoid any incompatibility with incoming wastes.

129. For bulk liquid wastes, stock control would involve maintaining a record of the route through the process, whereas drummed waste control should utilise the individual labelling of each drum to record the location and duration of storage.

130. The in-plant waste tracking system should hold all the information generated during pre-acceptance, acceptance, storage, processing and removal off-site. Records should be made and kept up to date on an ongoing basis to reflect deliveries, on-site treatment and dispatches. The tracking system should operate as a waste inventory/stock control system and include as a minimum:

- A unique reference number;
- Details of the waste generator and intermediate holders;
- Date of arrival on-site;
- Pre-acceptance and acceptance analysis results;
- Container type and size;
- Nature and quantity of wastes held on-site, including identification of associated hazards;
- Details on where the waste is physically located; and
- Identification of staff who have taken any decisions on acceptance or rejection of wastes.

131. The system adopted should be capable of reporting on all of the following:

- Total quantity of waste present on-site at any one time, in appropriate units;
- Breakdown of waste quantities being stored pending on-site processing;
- Breakdown of waste quantities on-site for storage only, that is, awaiting onward transfer;
- Breakdown of waste quantities by hazard classification;
- Indication of where the waste is located relative to a site plan;

- Comparison of the quantity on-site against total permitted; and
- Comparison of time the waste has been on-site against permitted limit.

3.3. Waste Storage and Handling

132. Once it has been determined that the waste is suitable for the installation, the operator should have in place systems and procedures to ensure that wastes are transferred to appropriate storage safely.

133. The issues for the operator to address in relation to measures for waste storage on the installation should include the following:

- Location of storage areas;
- Storage area infrastructure;
- Condition of tanks, drums, vessels and other containers;
- Stock control;
- Segregated storage;
- Site security; and
- Fire risk.

134. Useful information regarding storage of waste materials can also be found in the BREF for waste treatment industries (EIPPCB, 2006).

3.3.1 Design considerations

135. Transfer and storage areas should be designed to control accidental spills. This may require that:

- Adequately bunded and sealed storage areas, which are impermeable and resistant to the stored materials, should be provided to prevent spills from spreading and seeping into the soil;
- All spills should be collected, placed in a suitable container, and stored for disposal in the kiln;
- Incompatible wastes should be prevented from mixing in case of a spill;
- All connections between tanks should be capable of being closed via valves, and overflow pipes should be directed to a contained drainage system (that is, the relevant bunded area or another vessel);
- Leak free equipment and fittings should be installed whenever possible;
- Measures to detect leaks and take appropriate corrective action should be provided;
- Contaminated runoff should be prevented from entering storm drains and water courses (any such runoff should be collected and stored for disposal in the kiln); and
- Adequate alarms for abnormal conditions should be provided.

136. Storage design should be appropriate to maintain the quality of the wastes during the storage time. Segregated storage is necessary to prevent incidents from incompatible wastes and as a means of preventing escalation should an incident occur. Individual storage requirements on a particular installation will be dependent on a full assessment of risk.

137. Storage characteristics should consider the properties of the waste that poses greater risk that can be accepted at specific storage areas within the facility. In general, the storage of wastes needs, additionally, to take into account the unknown nature and composition of wastes, as this gives rise to additional risks and uncertainties. In many cases, this uncertainty means that higher specification storage systems are applied for wastes than for well-characterised raw materials

138. Containerised wastes should be stored under cover, protected from heat and direct sunlight, unless the waste is known to be unaffected by ambient conditions (sunlight, temperature, rain).

139. The design should prevent accumulation of hazardous wastes beyond the allowable period of time in the case of containerised wastes and should consider mixing or agitation to prevent settling of solids in the case of liquid wastes. It may be necessary to homogenise tank contents with mechanical or hydraulic agitators. Depending on the waste characteristics, some tanks may need to be heated and insulated.

140. Tanks, pipelines, valves, and seals must be adapted to the waste characteristics in terms of construction, material selection, and design. They must be sufficiently corrosion proof, and offer the option of cleaning and sampling.

141. Adequate ventilation should be provided in consideration to applicable work exposure guidelines (periodic monitoring for VOC emissions should be considered for open stored wastes that may emit VOC).

142. A fire protection system that meets all standards and specifications from local authorities (for example, local fire department) should be provided. Automatic fire detection systems should be used in waste storage areas as well as for fabric filters and electrostatic precipitators (ESP), electrical and control rooms, and other identified risk areas. Continuous automatic temperature measurement of the surface of wastes in the storage pits can be used to trigger an acoustic alarm in case of temperature variations.

143. Automatic fire suppression systems should be used in some cases, most commonly when storing flammable liquid waste although also in other risk areas. Foam and carbon dioxide control systems provide advantages in some circumstances, for example, for the storage of flammable liquids. Water systems with monitors, water cannons with the option to use water or foam, and dry powder systems are commonly used.

3.3.2 Operational considerations

144. There should be written procedures and instructions in place for the unloading, handling, and storage of wastes on-site. It should be ensured that chemical incompatibilities guide the segregation required during storage. Compliance with such procedures should be audited regularly.

145. To avoid the need for additional handling and transfer, a common practice is to ensure, as far as possible, that hazardous wastes are stored in the same containers (drums) that were used to deliver the wastes to the facility.

146. Designated routes for vehicles carrying specific hazardous wastes should be clearly identified within the facility. On-site transportation should be performed in a manner which minimizes risk to the health and safety of employees, the public and the environment. The operator should ensure that vehicles are fit for purpose with respect to compliance with relevant regulations. All loads should be properly identified, segregated according to compatibility (so that any potential spills do not create chemical safety hazards), and secured to prevent sliding or shifting during transport. Personnel should be directed and trained to use equipment only as intended, and not to exceed the rated capacity of containers, vehicles, and other equipment.

147. Appropriate signs indicating the nature of hazardous wastes should be in place at storage, stockpiling, and tank locations.

148. Containers should be kept in good condition (free of dents, not leaking or bulging), and closed when not removing waste. Container storage areas should be inspected at least weekly.

149. Maintenance work should be authorized by plant management, and carried out once a supervisor has checked the area and necessary precautions have been taken. Special procedures, instructions, and training should be in place for routine operations such as:

- Working at heights, including proper tie-off practices and use of safety harnesses;
- Confined space entry where air quality, explosive mixtures, dust, or other hazards may be present;
- Electrical lock-out, to prevent accidental reactivation of electrical equipment undergoing maintenance; and
- 'Hot works' (welding, cutting, etc.) in areas that may contain flammable materials.

150. The following measures should be considered to strengthen safety: